MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXXXI. FEBRUARY 11, 1921. No. 4

## ANNUAL GENERAL MEETING.

Professor FOWLER, F.R.S., PRESIDENT, in the Chair.

The Minutes of the preceding Annual General Meeting were read and confirmed.

The Report of the Auditors of the Treasurer's accounts for the year 1920 was read, and is given on p. 246.

The Annual Report of the Council was partly read.

The Address was delivered by the President, after which the Gold Medal was handed to Professor Henry Norris Russell, to whom it had been awarded for his contributions to the study of Stellar Evolution.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 351.

The thanks of the Meeting were given to the retiring Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

Cumberland Clark, F.R.G.S., F.Z.S., 22 Kensington Park Gardens, London, W. 11;

Robert Cochran Gray, M.A., B.Sc., University, Perth, Western Australia;

Masao Hasimoto, International Latitude Observatory, Mizusawa, Japan, and 35 Grantchester Street, Cambridge;

George Fredric Sowden Hills, B.A. (Camb.), Aston Grays, West End Avenue, Pinner;

Daniel James Jones, City Observatory, Cardiff, and 101 Mackintosh Place, Roath Park, Cardiff;

Edward Arthur Milne, B.A., Fellow of Trinity College, and Assistant Director of the Solar Physics Observatory, Cambridge;

George Morham, Fellow of the Faculty of Surveyors, 17 Mansionhouse Road, Edinburgh;

Cyril Potter, Dental Surgeon, 7 Balfour Road, Birkenhead;

Charles Bousfield Shaw, Member of the Bar, Secretary and Treasurer, Royal Agricultural Benevolent Institution, 8 Milborne Grove, The Boltons, London, S.W., 10; and

A. R. Stoney Smith, White Waltham Grove, near Maidenhead,

were balloted for and duly elected Fellows of the Society.

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The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Rev. Ivo Francis Henry Carr Carr-Gregg, M.A., Astley Vicarage, Nuneaton (proposed by E. Walter Maunder);

Walter George Gould, Lieut. R.N.R., A.M.I.N.A., L.C.C., Paddington Technical Institute (proposed by A. Fowler);

Stanley Robert Hewitson, B.Sc., Head Master, Royal Hospital Schools, Queen's House, Greenwich, S.E. 10 (proposed by P. J. Melotte);

Jan Krassowski, Ph.D., Director of the Observatory, Warsaw, Poland (proposed by Jules Baillaud);

Capt. Charles John Moorsom (late R.G.A.). Geodetic Surveyor, Civil Engineering Section of the Imperial College of Science and Technology, South Kensington, S.W. 7 (proposed by A. Fowler);

Capt. Austin Henry Quince, Lieut. R.N.R., Lecturer in Navigation and Nautical Astronomy, H.M.S. *Worcester*, Greenhithe, Kent (proposed by E. Fawcett White); and

Robert Stoneley, M.A. (Camb.), Mathematical Department, University of Sheffield (proposed by Harold Jeffreys).

## Report of the Council to the Hundred and First Annual General Meeting of the Society.

The following table shows the progress and present state of the Society:—

| | Patron | Honorary Member | Fellows | | Associates | Total |
|---|---|---|---|---|---|---|
| | | | Compounders | Annual Subscribers | | |
| 1919 December 31 ... ... ... ... | 1 | 1 | 226 | 489 | 50 | 767 |
| Since elected ... ... ... ... ... | ... | ... | +5 | +46 | ... | ... |
| Deceased ... ... ... ... ... ... | ... | ... | −5 | −10 | −2 | ... |
| Resigned ... ... ... ... ... ... | ... | ... | ... | − 6 | ... | ... |
| Since compounded ... ... ... ... | ... | ... | +4 | − 4 | ... | ... |
| Removed from list ... ... ... ... | ... | ... | ... | − 5 | ... | ... |
| Restored to list ... ... ... ... ... | ... | ... | ... | + 1 | ... | ... |
| 1920 December 31 ... ... ... ... | 1 | 1 | 230 | 511 | 48 | 791 |

(Six Associates are also Fellows, and are therefore counted twice in the above table.)

*Mr. Knobel's Account as Treasurer of the Royal*

RECEIVED.

| | £ s. d. | £ s. d. |
|---|---|---|
| Balances, 1919 December 31:— | | |
| At Bankers', as per Pass-book ... ... ... | 370 12 9 | |
| In hand of Assistant Secretary on Petty Cash Account ... ... ... ... ... | 11 7 0 | |
| In hand of Assistant Secretary on account of Turnor and Horrocks Fund ... ... | 5 2 2 | |
| | | 387 1 11 |
| Received on account of Dividends:— | | |
| £1,250 Metropolitan 3-per-cent. Stock ... | 29 1 3 | |
| £2,000 Swansea Corporation 3½-per-cent. Stock | 49 0 0 | |
| £3,500 East Indian Railway 3-per-cent. Debenture Stock ... ... ... ... | 73 10 0 | |
| £3,500 London and North-Western Railway 3-per-cent. Debenture Stock ... ... | 73 10 0 | |
| £4,000 Midland Railway 2½-per-cent. Debenture Stock ... ... ... ... ... | 70 0 0 | |
| £1,000 Lancashire and Yorkshire Railway 3-per-cent. Preference Stock ... ... | 21 0 0 | |
| £2,400 Gas Light and Coke Co. 3-per-cent. Debenture Stock ... ... ... ... | 50 8 0 | |
| £2,000 Commercial Gas Co. 3-per-cent. Debenture Stock ... ... ... ... ... | 42 0 0 | |
| £1,352, 12s. 6d. War Loan Inscribed 5-per-cent. Stock ... ... ... ... ... ... | 67 12 6 | |
| £275, 16s. 0d. War Loan 5-per-cent. Registered Stock ... ... ... ... ... ... | 13 15 8 | |
| £542, 18s. 2d. India 3½-per-cent. Stock ... | 6 13 0 | |
| | | 496 10 5 |
| Received on account of Subscriptions:— | | |
| Arrears ... ... ... ... ... ... | 198 14 0 | |
| Annual Contributions for 1920 ... ... ... | 789 12 0 | |
| ,, ,, ,, 1921 ... ... ... | 11 2 0 | |
| Admission Fees ... ... ... ... ... | 107 2 0 | |
| First Contributions ... ... ... ... | 78 15 0 | |
| | | 1185 5 0 |
| Compositions ... ... ... ... ... | | 231 0 0 |
| Amounts received in advance ... ... ... | | 8 5 0 |
| Sales of Publications:— | | |
| At Society's Rooms ... ... ... ... | 69 19 9 | |
| At W. Wesley & Son's ... ... £135 3 3 | | |
| Less 10 per cent. discount 13 9 10 | | |
| | 121 13 5 | |
| Herschel's Works: half share, received from the Royal Society ... ... ... ... | 4 0 0 | |
| | | 195 13 2 |
| Franklin-Adams Chart: received on account ... | | 40 0 0 |
| Sales of Photographs ... ... ... ... ... | | 68 7 9 |
| London Mathematical Society, for use of Rooms ... | | 20 0 0 |
| Income Tax refunded ... ... ... ... | | 173 17 0 |
| Mrs. Watson's Gift ... ... ... ... ... | | 300 0 0 |
| Cheques outstanding, 1920 January 1 ... ... | | 16 4 0 |
| ,, ,, 1920 December 31 ... ... | | 3 0 0 |

Examined and found correct.

(Signed) P. J. MELOTTE.
W. H. STEAVENSON.

1921 *February* 4.

£3,125 4 3

*Astronomical Society, from* 1920 *January* 1 *to December* 31.

PAID.

| | £ s. d. | £ s. d. |
|---|---|---|
| Assistant Secretary: Salary ... ... ... ... | 250 0 0 | |
| ,, ,, Editing Society's Publications | 50 0 0 | |
| Extra clerical assistance ... ... ... ... | 44 0 0 | |
| Clerk: Salary ... ... ... ... ... ... | 110 7 1 | |
| Porter and wife: Wages ... ... ... ... | 163 4 0 | |
| | | 617 11 1 |
| House Duty ... ... ... ... ... ... | 2 12 6 | |
| Fire Insurance ... ... ... ... ... | 10 13 0 | |
| Insurance of Stock at Printers' ... ... ... | 1 18 3 | |
| Servants' Insurance Stamps ... ... ... ... | 1 14 8 | |
| Accident Insurance ... ... ... ... ... | 0 18 11 | |
| | | 17 17 4 |
| Printing, etc.:— | | |
| Monthly Notices ... ... ... ... ... | 1390 10 6 | |
| List of Fellows and Miscellaneous ... ... | 107 16 3 | |
| Photo-engraving ... ... ... ... ... | 47 17 1 | |
| | | 1546 3 10 |
| Reproduction of Photographs for sale ... ... | | 61 11 2 |
| Franklin-Adams Chart: on Account ... ... | | 100 0 0 |
| Turnor and Horrocks Fund: Purchase of Books ... | | 23 18 5 |
| Expenses of Meetings of R.A.S. ... ... ... | 17 9 5 | |
| Report of Meeting on Relativity ... ... ... | 5 11 10 | |
| Expenses of Geophysical Committee ... ... | 10 14 10 | |
| Time Signal: Rental of Wire ... ... ... | 5 0 0 | |
| | | 38 16 1 |
| Telephone Subscription ... ... ... ... | 6 10 0 | |
| Registration of Telegraphic Address .. ... | 1 1 0 | |
| Postage, etc. (including postage of Monthly Notices) | 110 0 6 | |
| Carriage of Parcels ... ... ... ... ... | 0 16 7 | |
| Stationery and Office expenses ... ... ... | 18 1 11 | |
| Purchase of Scarce Numbers of Monthly Notices ... | 11 17 6 | |
| Binding Books for Library ... ... ... ... | 52 2 10 | |
| | | 200 10 4 |
| House expenses ... ... ... ... ... | 15 4 3 | |
| Coal, Gas, and Electric Light ... ... ... | 98 15 9 | |
| Sundry Fittings and Repairs ... ... ... | 17 0 10 | |
| Sundries ... ... ... ... ... ... | 4 7 0 | |
| | | 135 7 10 |
| Subscription Bureau Internat. pour Télégrammes Astronomiques ... ... ... ... ... | | 1 15 0 |
| Subscription Conjoint Board of Scientific Societies | | 10 0 0 |
| Lee and Janson Fund Grants ... ... ... | | 12 0 0 |
| Assistant Secretary for work for London Mathematical Society ... ... ... ... ... | 10 0 0 | |
| Expenses of Meetings of London Mathematical Society | 6 4 0 | |
| | | 16 4 0 |
| Purchase of £542, 18s. 2d. India 3½-per-cent. Stock | | 300 0 0 |
| Cheque book and charges on cheques ... ... | 1 1 0 | |
| Deficiency on French P.O. Orders ... ... ... | 0 2 0 | |
| | | 1 3 0 |
| Cheque outstanding, 1920 January 1 ... ... | | 3 0 0 |
| Cash not paid in ... ... ... ... ... | | 2 2 0 |
| Balances, 1920 December 31:— | | |
| At Bankers', as per Pass-book ... ... ... | 24 12 10 | |
| In hand of Assist. Sec. on Petty Cash Account | 11 7 7 | |
| ,, ,, on Account of Turnor and Horrocks Fund | 1 3 9 | |
| | | 37 4 2 |
| | | £3,125 4 3 |

*Report of the Auditors.*

We have examined the Treasurer's accounts of receipts and expenditure for the year 1920, and have found and certified the same to be correct. The cash in hand on 1920 December 31, including the balance at the bank, etc., amounted to £37, 4*s.* 2*d.*

The funded property of the Society has been increased by the purchase of £542, 18*s.* 2*d.* India 3½-per-cent. Stock, purchased with Mrs. H. J. Watson's gift of £300.

The books, instruments, and other effects appear to be in a satisfactory condition.

A list has been laid on the table of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

The certificates of railway and other stocks have been examined, and the stocks inscribed at the Bank of England verified.

(Signed) P. J. Melotte.
W. H. Steavenson.

1921 *February* 4.

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*Gifts to the General Funds of the Society.*

In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

*The Lawson Bequest* (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

*The Carrington Bequest* (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2,000 Consols.

*The Lambert Bequest* (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

*The McClean Bequest* (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2,000, free of legacy duty.

*The Farrar Bequest* (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

*Trust Funds.*

*The Lee and Janson Fund*: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334, 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

| | £ | *s.* | *d.* | | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|---|
| 1920 Jan. 1. Balance of Fund ... ... | 39 | 3 | 1 | 1920. Grants from Fund | 12 | 0 | 0 |
| 1920. Dividends, East Indian Railway ... | 10 | 0 | 9 | 1920 Dec. 31. Balance of Fund ... ... | 37 | 3 | 10 |
| | £49 | 3 | 10 | | £49 | 3 | 10 |

*The Turnor Fund and the Horrocks Memorial Fund*: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464, 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38, 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks: to this the Society added the sum of £55, 15*s.*, and the whole now stands in £103, 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

| | £ | *s.* | *d.* | | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|---|
| 1920 Jan. 1. Balance of Fund ... ... | 11 | 4 | 10 | 1920. Purchase of Books | 23 | 18 | 5 |
| 1920. Dividends, East Indian Railway ... | 17 | 1 | 0 | 1920 Dec. 31. Balance of Fund ... ... | 4 | 7 | 5 |
| | £28 | 5 | 10 | | £28 | 5 | 10 |

*The Hannah Jackson (née Gwilt) Fund*: In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309, 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

| | £ | *s.* | *d.* | | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|---|
| 1920 Jan. 1. Balance of Fund ... ... | 47 | 6 | 5 | 1920 Dec. 31. Balance of Fund ... ... | 56 | 12 | 5 |
| 1920. Dividends, East Indian Railway ... | 9 | 6 | 0 | | | | |
| | £56 | 12 | 5 | | £56 | 12 | 5 |

*The Sir David Gill Bequest* (1919): The following is an extract from the Will of the late Sir David Gill:—

> I direct my Trustees and Executors to pay to the Royal Astronomical Society of London (the receipt of the Secretary for the time being a full and efficient discharge) the sum of two hundred and fifty pounds to be employed by the Council of the said Society in aid of Astronomical Research, and I desire to declare that I make this bequest in grateful remembrance of a like sum paid out of the funds of the said Society in aid of my expedition to Ascension in the year one thousand eight hundred and seventy-seven, and I express a wish that the said sum be devoted in part or in whole to some expenditure of a like character to complete some great work, such as the computation of New Tables of the Satellites of Jupiter or other like undertaking of fundamental importance to Astronomy, but I expressly provide and declare that the same shall not be applied to Eclipse Expeditions, as these are now recognised as objects which are provided for by Government or other funds.

This sum now stands in £275, 16*s.* 0*d.* 5-per-cent. War Loan Registered Stock. Interest accrued, £13, 15*s.* 8*d.*

*The Harry Watson Fund*: In 1920 Mrs. Watson presented to the Society the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the Library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s.* 2*d.* India 3½-per-cent. stock. Interest accrued, £9, 10*s.* 0*d.*

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*Assets and Present Property of the Society, 1920 January 1.*

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Balances, 1920 December 31:— | | | | | | |
| At Bankers', as per Pass-book ... ... ... | 24 | 12 | 10 | | | |
| In hand of Assistant Secretary on Petty Cash Account ... ... ... ... ... | 11 | 7 | 7 | | | |
| In hand of Assistant Secretary on account of Turnor and Horrocks Fund ... ... | 1 | 3 | 9 | | | |
| | | | | 37 | 4 | 2 |
| Due on account of Subscriptions:— | | | | | | |
| 2 Contributions of 4 years' standing ... ... | 16 | 16 | 0 | | | |
| 10 ,, 3 ,, ,, ... ... | 63 | 0 | 0 | | | |
| 31 ,, 2 ,, ,, ... ... | 130 | 4 | 0 | | | |
| 56 ,, 1 ,, ,, ... ... | 117 | 12 | 0 | | | |
| 1 Admission Fee and First Contribution ... | 3 | 3 | 0 | | | |
| Other sums ... ... ... ... ... | 3 | 3 | 0 | | | |
| | 333 | 18 | 0 | | | |
| Less paid in advance ... ... ... | 19 | 7 | 0 | | | |
| | | | | 314 | 11 | 0 |
| Due for Photographs sold ... ... ... ... | | | | 0 | 12 | 0 |
| Due from Wm. Wesley & Son for sales of Publications during the last quarter of 1920 ... ... | | | | 24 | 7 | 8 |

£1,250 Metropolitan 3-per-cent. Stock.

£2,000 Swansea Corporation 3½-per-cent. Stock.

£3,500 East Indian Railway 3-per-cent. Debenture Stock.

£3,500 London and North-Western Railway 3-per-cent. Debenture Stock.

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£1,000 Lancashire and Yorkshire Railway 3-per cent. Consolidated Preference Stock.

£2,400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock.

£1,352 12s. 6d. War Loan 5-per-cent. Inscribed Stock.

£275, 16s. 0d. War Loan 5-per-cent. Registered Stock.

£542, 18s. 2d. India 3½-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, etc.

Stock of Publications and Photographs.

Two Gold Medals.

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*Celestial Photographs.*

The following have been added to the list of Celestial Photographs reproduced by the Society for sale to the Fellows :—

R.A.S. Ref. No.

299. 72-inch Reflector, Victoria, B.C.
300. Spectrograph of 72-inch Reflector, Victoria, B.C.
301. Sun-spot, 1919 Oct. 8, Royal Observatory, Greenwich.
302. Sun, 1920 Jan. 25, Royal Observatory, Greenwich.
303. Sun-spots, 1920 Mar. 19, Royal Observatory, Greenwich.
304. Sun-spots, 1920 Mar. 20, Royal Observatory, Greenwich.
305. Sun-spots, 1920 Mar. 21, Royal Observatory, Greenwich.
306. Sun-spots, 1920 Mar. 22, Royal Observatory, Greenwich.
307. Sun-spots, 1920 Mar. 23, Royal Observatory, Greenwich.
308. Sun-spots, 1920 Mar. 25, Royal Observatory, Greenwich.
309. Nebulosity S. of $\zeta$ Orionis, 100 in., Mount Wilson Observatory.

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*Publications of the Society.*

During the past year vol. lxxx. of the *Monthly Notices* has been published, also *Memoirs*, Appendix to vol. lxii.

## Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Sir William de W. Abney.
Thomas William Backhouse.
Eric Doolittle.
Isaac Engelson.
William Earnshaw Etzel.
David Fleming.
Spencer Lavington Fletcher.
A. ffolliott Garrett.
John Grigg.
Maxwell Hall.
* George William Jones.
Philip H. Kempthorne.
Henry Herbert Lee.
Sir Edmund Giles Loder.
Fiammetta Wilson.
Associates :—Giovanni Celoria.
Karl Hermann Struve.

An obituary notice of Sir Joseph Norman Lockyer is also given, since he was a Fellow of the Society for thirty-five years, though he resigned his Fellowship some years before his death.

Sir William de Wiveleslie Abney, K.C.B., F.R.S., better known by a former familiar designation as Captain Abney, R.E., whose death during the past year we have to record, was one of the Fellows of the Society, of whom there have been other examples, whose activities lay in a branch of science other than astronomy, but have been chosen to occupy the Presidential chair because they excelled in some branch that had close relation to our science. Sir William Abney was worthily famous for his knowledge of the theory and practice of photography, of colour, and of light in general, and this knowledge was put freely at the service of astronomy. In this note it will scarcely be possible to follow in detail all his researches in these matters, but it may be sufficient to record the incidents of his career which connect him specially with astronomy.

Lieutenant Abney of the Royal Engineers, then attached to the Military School of Engineering at Chatham, where he had charge of a small photographic and chemical laboratory and was afterwards (1874) Instructor in these sciences, joined the Royal Astronomical Society on 1870 April 8, and his active participation in astronomical affairs began a few years later in connection with

* Died 1918 November 4 ; death not reported till 1921.

the observation of the Transit of Venus. It will be remembered that for the purpose of observing that phenomenon, which happened in 1874 December, a large sum of money had been supplied by the Government and a band of observers collected, mainly from the naval and military services, who learned the use of their instruments and practised observing at the Royal Observatory, Greenwich, under the direction of Sir George Airy. In 1871, at the instigation of Mr. De La Rue, photographic observation of the Transit was added to the scheme, a further sum of money being supplied for the purpose, and later on sapper engineers, who had been trained at Chatham, and others were added to the personnel as photographers. Captain Abney (he attained the higher rank in 1873) went to Greenwich to advise and superintend the photographic part of the preparations.

The nature of the help that he gave in this work will be judged from a paper by him in the *Monthly Notices*, **34**, 275, dated from Greenwich, 1874 March 7, in which he describes a method for preparing dry plates for solar photography, and their development. The pyrogallic development that Mr. De La Rue had used with much success for delineating the Sun's disc did not appear to give the sharpness of limb necessary for accurate measurements, but the albumen dry-plate process perfected by Captain Abney was said to give a fine deposit and a sharp limb free from halation with a moderate exposure, and it was decided to adopt this not only by the English but also by the German and Russian expeditions. For actual observation of the Transit, Abney joined the Egyptian party, and was stationed at Thebes with Colonel Campbell and near to Dr. Auwers of the German expedition. The report of his observations will be found in *Monthly Notices*, **35**, 208. It did not anticipate that any great success would follow from measurement of the plates he exposed, though he was favoured with fine, but misty, weather, and, as was afterwards realised, the photographic part of the programme had to be regarded as a failure. The concluding paragraph of the volume recording the British observations of the Transit of Venus runs:—

> "The number of images thus taken and entered was: At Thebes 83, at Rodriguez 146, at Roorkee 53. But they have not been further reduced. The ardour of the observers had been much cooled by the apparent general failure of the photographic principle, and they were unwilling to spend further time on these reductions."

It may be added that in his Report to the Board of Visitors for 1872 Sir George Airy wrote: "It is unnecessary for me to remark that our hope of success is founded entirely on our confidence in Mr. De La Rue."

Abney's reputation as a scientific investigator at this time may be inferred from an introductory remark to a paper that he read before the British Association in 1875 to the effect that he had been called upon by the War Office to undertake photometric measurements of certain magneto-electric lights. In the course of the experiments for this purpose he carried out measurements

of the actinic value of the same lights, and brought to the notice of the Society in 1875 June an instrument of the nature of a photometer called a diaphanometer, that he had designed for these determinations. The next communication by Abney (*Monthly Notices*, 1876 March) was a preliminary note on the very extensive investigation made by him of the photography of the infra-red end of the spectrum, in which he referred to methods carried out in the two previous years by Professor Vogel and Captain Waterhouse; but whereas these gentlemen had found that with a red dye the collodion was most sensitive to the red end, he, by mixing gum resins with the collodion, had obtained a compound sensitive to long wave-lengths in a greater degree. The account of his further research on this subject is to be found in the *Monthly Notices* for 1878 April, and in the Memoir published in the *Philosophical Transactions*, 171, pt. 2, p. 653, which was given as the Bakerian lecture in the year 1880, and comprises the map of the infra-red parts of the solar spectrum as photographed by him, in which the prismatic spectrum could be traced as far as wave-length 12,000 tenth-metres. By a later development he produced an emulsion of bromide of silver which was sensitive not only to red and infra-red rays, but also to the heat rays given out by bodies far below the incandescent point (*Phil. Trans.*, 1886), and he is said to have photographed a boiling kettle in a completely dark room. His treatise on photography in Longman's Text-books of Science Series appeared in 1876, and in the same year he produced a third edition of his smaller book, *Instruction in Photography*, first published in 1870, of which a seventh edition was called for in 1886. *Photography with Emulsions* appeared in 1878. A book of another kind, *Thebes and its Five Great Temples*, the outcome of his expedition to observe the Transit of Venus, appeared about the same time. Abney was elected to Fellowship of the Royal Society in 1876. He had a seat at the council table of the Royal Astronomical Society in 1875 and in 1876, and after an interval of some years was elected again in 1883. From that time forward he sat at the table continuously, except in the years 1886 and 1900, either as President, Vice-President, or Ordinary member until the year 1907. In 1877 he gave up his post at Chatham and became officially connected with the Science Department at South Kensington. He held the post of Inspector of Local Schools until 1884, when he was made Assistant Director of the Science Division under Sir John Donnelly, and on reorganisation of the Department in 1899 became Principal Assistant Secretary of the Board of Education, Secondary Branch, at South Kensington, and held the post until 1902, after which date he acted as honorary Adviser to the Board of Education (Science Department).

Of the papers communicated to our Society by Abney, a short note on 1877 March, discussing the effect of a star's rotation on its spectrum, with the conclusion that rotation would exhibit itself as a total broadening of the line consisting of a sort of double

penumbra and a black nucleus, seems to embody an idea, worthy of consideration at the present time, when idiosyncrasies of spectral lines are held to prove so much; and, writing broadly, the other communications deal mainly with points connected with the measurement of the light emitted by the heavenly bodies. One (1887 March) is an excerpt from or summary of a paper communicated to the Royal Society on the loss of light of different wave-lengths by transmission through varying thickness of atmosphere; in another (1889 March), scales of density on photographs are evaluated, whilst others deal with the scaling of wedges for photometry and points relating to the precise determination of star magnitudes by photography. Methods of determination of the comparative brightness of the corona at different parts of its surface were subjects to which Abney gave attention, and he was consulted and arranged methods for the photometric and photographic programme to be followed in the observation of eclipses. It was arranged that he should go with Mr. Lockyer and assistants as the Government Expedition to Egypt to observe the total solar eclipse of 1882 May 17, but Abney was prevented by ill-health, and his place was taken by Dr. Schuster. To observe the eclipse of the next year, 1883 May 6, Messrs. Lawrance and Woods, who had accompanied Mr. Lockyer in 1882, went to the Caroline Islands and successfully carried out a photographic programme arranged by Lockyer and Abney. As President of the Society from 1893 to 1895, he occupied the chair with dignity, occasionally diversified by sparks of quiet humour; and his second Presidential address, which was to Dr. Isaac Roberts, in the course of which he spoke of a thirty-two years' experience in every past or present photographic process that had impressed deeply on his mind the remarkable strides that the science of photography had made since he first developed a wet plate, must have been congenial.

It is not proposed to give here a detailed account of the many papers Abney contributed to the Proceedings of the Royal, the Physical, and other Societies, and to other publications, of which more than a hundred appear in the Royal Society catalogue, under either his name alone, or conjointly with that of others. These are, for the most part, on the subjects of colour and colour photometry, and a series of researches, based on the principle of Rumford's shadow photometer, in which the relative brightness of light of different wave-length was determined, made in conjunction with Major-General Festing, who was his collaborator also in other work, formed the subject of the Bakerian lecture in the year 1886 and of a memoir read before the Royal Society on 1888 May 31. The titles of books by Abney, *Colour Vision, Colour Measurement and Mixture* (1893), *Trichromatic Theory of Colour* (1914), are sufficiently explanatory of their contents, and indicate the energy the author exhibited in this branch of science. It is well known that Abney continually had before him the problem of photography in natural colours, and that much of the

success of the three-colour process, and of other methods of photographic reproduction, is due to his thought and experiments.

The paper before mentioned, "On Transmission of Sunlight through the Atmosphere," was the result of observations made in London, and at a height of 8000 feet on the Riffel in Switzerland, which must have been a pleasing occupation, for Abney was a keen mountaineer and frequent visitor to the Swiss mountains. A book of which he is the author, with C. D. Cunningham, *Pioneers of the Alps*, was published in 1888.

As to other personal facts, William de Wiveleslie Abney was the eldest son of Canon Abney, vicar of St. Alkmund's, Derby, and of Measham Hall, Leicestershire, and was born at Derby on 1843 July 24. He was educated at Rossall, and was gazetted Second Lieutenant R.E. in 1864. Besides the Presidency of our Society, already mentioned, he was President of the Physical Society from 1895 to 1897, and chairman of the Royal Society of Arts in 1904. He served on the Council of the Royal Society in the years 1883–85 and 1891–93, and received the Rumford Medal in 1882, a distinction which is awarded particularly to the author of a discovery on heat or light. Abney was a member of the Solar Physics Committee from its beginning in 1879, and was President of Section A at the British Association in 1889. In 1897 he was chosen to be a member of the Board of Visitors of the Royal Observatory, Greenwich, as representative of the Royal Astronomical Society, and evidently felt himself called on to exercise his special knowledge at the annual visitation. The writer of this note well remembers a short impromptu lecture on developers given on one occasion by Sir William Abney to a knot of the junior staff who chanced to be gathered near him. He was created K.C.B. in the year 1900. Sir William Abney died at Folkestone on 1920 December 2, leaving a widow, a daughter by this, his second marriage, and a son and two daughters by his first wife. An obituary note bearing testimony to his genial temperament and delightful companionship, by a sympathetic friend and comrade, Mr. A. E. H. Tutton, will be found in *Nature* for December 9.

As already stated, he was elected a Fellow of the Society on 1870 April 8. H. P. H.

Thomas William Backhouse was the eldest son of Thomas James Backhouse of Sunderland, where he was born on 1842 August 14. He was educated at the Grange School, Sunderland, the Friends' Boarding School, Bootham, York, and at University College, London.

For a short period he was at Backhouse's Bank, Sunderland, but except for attendance at colliery meetings in the capacity of a Director, he was not subsequently engaged in business.

For the greater part of his life he was resident at West Hendon House, Sunderland, where he had an observatory erected furnished with a $4\frac{1}{4}$-inch Cooke equatorial refractor.

His interest in astronomy, natural history, meteorology, etc., began in his school days at York, where he started a diary which he called "A Journal of Natural History." As his astronomical studies deepened, however, he entered his records of observations of celestial phenomena in a separate "Astronomical Journal" which, begun in 1858, finally extended to 36 volumes.

His astronomical work covered a wide range, and the results of his studies are published in numerous papers in the *Monthly Notices*, the *Publications of the West Hendon House Observatory*, and elsewhere. They include such varied subjects as auroræ, the zodiacal light, the green flash, observations of variable stars, new stars, eclipses, comets, meteors, and the structure of the universe. His earliest paper communicated to the Society was "On the Aspect of the Zodiacal Light opposite the Sun," which describes the phenomenon known as the Gegenschein, to which he was one of the first to draw attention (*M.N.*, **36**, 46).

In 1911 he published a *Catalogue of* 9842 *Stars visible to the Naked Eye*, in which he collected the magnitude determinations from various authorities, assigned adopted values, and gave the positions for 1900. This was intended as a preliminary to a new series of 14 large maps of the naked-eye stars on the gnomonic projection for the use of meteoric observers. The catalogue was presented to the leading observatories and astronomers of the world. The maps were not quite completed when he died, but provision was made for them to be printed and circulated in a similar manner.

On four occasions he went abroad to observe a total eclipse of the sun, viz. once to India and three times to the Spanish Peninsula. He was favoured with fine weather every time. He also intended to go to Norway in 1914, but, the war breaking out the day before he was to start, he was unable to do so.

Backhouse was a very close observer of the weather, and his records for Sunderland were fairly complete from 1857 to the time of his death. In 1918 and 1919 he served as Vice-President of the Royal Meteorological Society.

He was extremely fond of children, and he was keenly interested in educational matters. For a considerable time he was a member of the Sunderland School Board, and he made a point of visiting every school at least once in the year.

He passed away at his home in Sunderland after a brief illness on 1920 March 13, and his remains were interred in the Friends' Burial Ground in the Bishop Wearmouth Cemetery.

He was elected a Fellow of the Society on 1873 April 9.

Eric Doolittle was born at Ontario, Indiana, on 1869 July 26. He was the son of Charles Leander Doolittle, Professor of Astronomy and Mathematics at Lehigh University from 1885 to 1895, and later Professor of Astronomy at the University of Pennsylvania and first Director of the Flower Observatory. He received his education in the Schools at Bethlehem, Pa., and at

the Preparatory School of Lehigh University, graduating at the University as civil engineer in 1891. During the next two years he was instructor in mathematics at Lehigh University and the University of Iowa, and in 1894 went to the University of Chicago for post-graduate work in astronomy. It was during his stay there that he began those studies which led up to his memoir on "The Secular Variations of the Orbits of the Four Inner Planets," which was published in 1912 by the American Philosophical Society as vol. xxii., part 2 of their *Transactions*.

In 1896 he left the University of Chicago for that of Pennsylvania, where he worked as instructor in astronomy and his father's assistant at the Flower Observatory. Here he took charge of the very fine 18-inch Brashear refractor of 30 feet focal length, and with indefatigable energy threw himself into the measurement of double stars with the micrometer. On his father's retirement in 1912 he was appointed Director of the Observatory. He still had a large amount of teaching work to do, in which he displayed the valuable faculty of imparting to his students something of his own enthusiasm; but it is mainly as an observer that he made his greatest contributions to astronomy. In his comparatively short life he accomplished a truly remarkable work, publishing between 1901 and 1914 the following volumes: *Measures of* 900 *Double and Multiple Stars*, *Measures of* 1066 *Double and Multiple Stars*, *Catalogue and Remeasurement of* 648 *Double Stars discovered by G. W. Hough*, and *Measures of* 1954 *Double Stars*. In addition he made, subsequently to 1914, some thousands of measures, which will occupy a further volume. Doubtless the greatest honour conferred upon him was when, in 1910, S. W. Burnham of the Yerkes Observatory, on his retirement, recognising his great abilities, entrusted to him the work of extending his *General Catalogue of Double Stars* (1906), handing over to him at the same time his library and the large amount of data he had already accumulated. At the time of his death he had compiled a card catalogue and made considerable progress with the work.

Despite the exacting demands of his professional labours, he contributed a number of articles on astronomical subjects to various journals.

During the war he organised and conducted the U.S. Shipping Board Navigation School at Philadelphia, where, being short of adequate assistance, he broke down under the strain; and, although subsequently he returned to the Observatory, he never completely recovered. In 1920 May he was again taken ill, and died in the University Hospital on September 21.

In disposition Eric Doolittle was modest and retiring. He possessed an intense enthusiasm for his work, but did not often attend meetings or take part in public discussions. He was a man of many interests, and was especially fond of the writings of Charles Dickens.

He married in 1902 Sara Halliwell, who survives him.

He was elected a Fellow of the Society on 1898 March 11.

Canon David Fleming, who died at the age of ninety years, was educated at the University of Glasgow, graduating in 1856 and taking holy orders two years later. After holding curacies in Leeds, Grosmont, and West Hartlepool, he accepted the living of Coxhoe in 1867, and held the benefice for half a century. During his vicariate the present parish church was completed and the schools built.

On the death of Canon Barnet a few years ago, he was appointed honorary canon of Durham Cathedral.

He took a deep interest in astronomy, and used a 5-inch reflecting telescope.

He was elected a Fellow of the Society on 1878 January 11.

Spencer Lavington Fletcher was born near Manchester in 1870. He was educated at Owens College, Manchester, and at the Royal College of Science, London, where he took a first class in astronomical physics.

From 1898 he was well known as a lecturer on astronomy and physiography, and delivered over 2000 lectures to schools and local scientific societies. In delivering these, he exercised great care in making his subject both clear and interesting to the uninstructed. His astronomical studies were of a very general character, but he devoted a considerable part of them to the history of the science and the apparatus used in connection with it.

It does not appear that Mr. Fletcher published any work, though reports of his lectures are no doubt published in the transactions of some of the societies which he visited. It is understood that he left a book in manuscript, intended for publication.

Mr. Fletcher died on 1920 November 11 at 1 Courtfield Gardens, West Ealing, where he had resided for some time. He has left a widow (to whom he was married on 1909 July 9), but no family.

He was elected a Fellow of the Society on 1901 November 8.

Major Arthur ffolliott Garrett, O.B.E., R.E., was the youngest son of Mr. W. Raymond Garrett of Kilgaran, Co. Carlow, and was born on 1875 April 27. He was educated at Clifton College and Woolwich, whence, after being second at his entrance, he passed out first of his year, gaining the Pollock Medal and obtaining a commission in the Royal Engineers. For some time he served in India in the railway branch of the Public Works Department. Later he became Assistant State Engineer of Jeypore State, where he received his first training as an irrigation engineer from the late Col. Sir Swinton Jacob. After further experience on railway surveys he became State Engineer of Alwar State, and successfully applied his theory of arched masonry dams to the construction of the Agar dam. It was, however, by his work in connection with the irrigation branch of the Public Works Department in the Central Provinces that he specially distinguished

himself. He revolutionised the design of reservoir spill-ways, which effected a considerable saving of expense to the Government, and followed this up by designing a hydraulic system for irrigation canals which has since been largely adopted in every province throughout India.

On the outbreak of the war in 1914 he was recalled to military duties. He was wounded in the Suvla Bay landing at Gallipoli in 1915, and was afterwards sent to India, where he was appointed A.C.R.E. at Karachi. On the outbreak of the Afghan war he was appointed C.R.E. of the 2nd Division. Later, in the intense heat in Peshawar, his health broke down, and, despite a short rest in the hills, he was attacked by malaria in an acute form, and ordered home. He died, however, in a hospital at Marseilles on 1920 March 28.

Major Garrett was greatly interested in astronomy, and restored the old observatory at Jeypore while stationed there as State Engineer. He also possessed a large reflecting telescope, and intended in the days of greater leisure to which he looked forward to devote his time largely to the science.

In 1900 he married Ida, the daughter of the late Rev. J. F. A. Gawin, who survives him.

He was elected a Fellow of the Society on 1905 January 13.

John Grigg was born in 1838 in the Isle of Thanet, being the youngest son of James Grigg. He received a musical, scientific, and commercial education, his father being a prominent member of the firm of Wells & Co. After his father's death he was engaged successively in the music and furnishing trades, giving much of his spare time to choral singing; thus he sang in the Handel Festival in 1857. He settled in New Zealand in 1863, living in Auckland till 1868 and then moving to Thames, where he remained till his death.

He taught singing under the Education Board, with very successful results. A song that he composed, "My own New Zealand Home," is stated to rank almost as a national anthem. He was for a long time the conductor of the Thames Choral Society, which he helped to found, and was for ten years the organist and one of the trustees of the Baptist Church.

The occurrence of the Transit of Venus in 1874 revived an interest in astronomy which he had shown in boyhood, and he made successful observations both of that transit and its successor in 1882. He then erected an observatory, with transit circle and equatorial, which was completed in 1884.

He joined the British Astronomical Association in 1897, working with special zeal and success in the comet section. He devised a semi-graphical method of forming ephemerides of periodic comets, and it was with the aid of a self-constructed ephemeris that he was the first to detect Encke's Comet at its 1898 return, in which the conditions were unusually difficult, the only other observer being Mr. Tebbutt.

Grigg also discovered three unexpected comets. In the case of 1902 II. there was an unfortunate miscarriage of a message addressed to Mr. Baracchi at Melbourne, so that Grigg was the sole observer and the sole orbit computer. But the comets 1903 III. and 1907 II. were both well observed. In the latter case there was again a delay in distributing the news, and Mr. Mellish of Washburn Observatory found the comet independently, five days after Grigg; it is known as Grigg-Mellish.

Grigg received two medals from the Astronomical Society of the Pacific for his cometary discoveries. He was also successful in cometary photography, obtaining one of the few good plates of the bright comet 1901 I.

Grigg also did good work in spreading astronomical knowledge by frequent lectures, and the contribution of regular notes to the *Otago Witness*.

He died on 1920 June 20, at the age of 82, leaving a son, Mr. Felix Grigg, who is working in the Dominion Laboratory, Wellington, N.Z.

He was elected a Fellow of the Society on 1906 June 8.

A. C. D. C.

Maxwell Hall, Barrister-at-Law, the son of John and Charlotte Hall, was born at Cheltenham in 1845. He was educated at a private school and subsequently at King's College, London, and Pembroke College, Cambridge, graduating as a Wrangler in 1871. In the following year he settled in Jamaica and erected an observatory furnished with a 3-inch transit instrument and a 4-inch equatorial refractor, both by Messrs. Cooke of York. In the course of his astronomical work he observed Mars at the favourable opposition of 1877, and deduced the value $8''{\cdot}789 \pm 0''{\cdot}060$ for the solar parallax (*Memoirs*, 44, 52), which is in very close agreement with the value $8''{\cdot}78 \pm 0''{\cdot}012$ derived by Sir David Gill from observations of Mars at the same opposition.

In 1883 and again in 1915 he deduced the rotation-period of Neptune from observations of temporary variations in the planet's light, obtaining the values $7^h\ 55^m$ (*M.N.*, 44, 257) and $7^h\ 50^m\ 6^s$ (*M.N.*, 75, 626) respectively. He also observed Halley's Comet in 1910 (*M.N.*, 70, 615).

A problem in which he was specially interested was that of the sidereal system, and in vol. xliii. p. 157 of the *Memoirs* is a paper by him on this subject. Starting from the assumption that there is "some point of space, material or immaterial, in motion or at rest," round which the sun and stars revolve, he concluded that the centre is neither *Alcyone*, as Mädler had suggested, nor in the constellation *Perseus*, as suggested by Argelander, but lies somewhere on the line passing through the sun and two regions in *Andromeda* and *Hydra* (below *Corvus*) respectively, and at such a distance that the sun and neighbouring stars move round it with almost the same velocity. As viewed from the sun this centre is in R.A. 9° 15′, N.P.D. 63° 28′, which is almost 1° *sp* the $6^m$ star

65 Piscium. The centre itself he considered likely to be in the Galactic plane, though, since the sun is apparently situated somewhere to the N. of that plane, its projected direction lies below it. From the data to hand he deduced that the period of revolution is 20,000,000 years, "the Annus Magnus which restores all the stars to their same relative positions."

This theory was three times revised. At the first revision in 1887 (*M.N.*, 47, 521), with the increased data from annual parallaxes and radial velocities available, elliptical motion was introduced for some of the stars, the centre was moved to R.A. 10° 56′, N.P.D. 61° 36′, and the Annus Magnus reduced to 13,150,000 years. The second revision was made in 1896 (*M.N.*, 57, 357), after the publication of the photographic determination of the radial velocities of 51 stars at Potsdam and the parallaxes of 26 stars at the University Observatory, Oxford. Advantage was also taken of the greater accuracy of stellar proper motions as deduced by Auwers. On the whole the effect of the new material was to diminish the radial velocities and to increase the parallaxes, which involved some readjustment of the constants. A comparison with the available data showed a distinct improvement in the results thus obtained. In 1898 the third revision was made (*M.N.*, 58, 473), the solar orbit, which had hitherto been assumed to be circular, receiving a slight correction. This produced a still better agreement between the theory and the facts then to be explained.

But a large part of his scientific work lay in the field of meteorology. In 1880 he was appointed Government Meteorologist, and did valuable work in organising the meteorological service of the Island. He was specially interested in hurricanes and earthquakes, and published a number of reports on these and other scientific subjects.

His death occurred on 1920 February 20.

He was elected a Fellow of the Society on 1878 May 10.

The Rev. Philip Henry Kempthorne, the son of the Ven. Richard Kempthorne, was born at St. Helena in 1841 April 1. He entered Uppingham School in 1859, and, obtaining a scholarship at St. John's College, Cambridge, graduated in 1863, being placed eighth in the first class in the Classical Tripos. He became a Fellow of his College in 1866.

In 1867 he accepted a post as Assistant-Master at Wellington College under Dr. Benson, and was ordained by the Bishop of Oxford in the following year. He remained at Wellington for no less than twenty-eight years, and among his pupils were the Princes Francis and Adolphus, brothers of Queen Mary, and also the present Lord Derby.

In 1873 he married Annie Elizabeth, a daughter of Mr. Robert Badcock of The Elms, Taunton.

In 1904 he was presented to the living of Wyck Rivington, Gloucestershire, where he remained till 1917. In that year he

returned to the neighbourhood of Wellington College, and took up his residence at Crowthorne, where he died on 1920 May 5.

His most active astronomical work was done as a member of several of the observing sections of the British Astronomical Association, including those for the study of the star colours, Saturn, Mars, and Jupiter; his observations being obtained by means of a $12\frac{1}{2}$-inch reflector by Calver, and a $3\frac{3}{4}$-inch refractor by Wray.

He was elected a Fellow of the Society on 1883 May 12.

Major-General Henry Herbert Lee, C.B., O.B.E., J.P., was born at The Mount, Duras Powys, Glamorganshire, in 1838, his father being the Rev. Henry Thomas Lee, at one time rector of Wenvoe. He was educated at Marlborough and at Addiscombe College (the College of the old East India Company), and after obtaining a commission in the army served for a considerable time with the Bombay Engineers. He saw active service in the Abyssinian War, and was stationed at the base of operations at the time of General Roberts' famous march to Kandahar. He was on duty at home from 1878 to 1883, but in the latter year went out to Egypt and served under General Wolseley. He retired from the army in 1886, and spent the remainder of his life in his native country, throwing himself with unwearying energy into a variety of movements—religious, social, educational, and recreative—which tended to the betterment of his fellow-men. He also maintained his interest in military matters, was one of the original members of the Glamorgan Territorial Association, and gave his most hearty support to such organisations as the Church Lads' Brigade and the Boy Scouts movement. About two years before his death he was appointed Deputy Lord-Lieutenant for Glamorgan. He also took a very active part in ecclesiastical affairs, and was a member of the House of Laymen of the Province of Canterbury.

Amongst his many and varied activities he found time for astronomy, and set up a fine 6-inch Cooke equatorial furnished with spectroscope for solar and stellar work. These instrumemts he was always glad to place at the disposal of any student of astronomy. He was at one time President of the Astronomical Society of Wales, and served on its Council from its formation.

In 1873 he married Constance Mary, daughter of Mr. George Lyall of Headley Park, near Epsom. There were no children of the marriage, and his wife died about twenty years before him.

He died on 1920 March 12.

He was elected a Fellow of the Society on 1907 June 14.

Sir Joseph Norman Lockyer was born at Rugby, 1836 May 17. He was educated at private schools and on the Continent. He entered Government service as a clerk in the War Office in 1857; and all his earlier astronomical work was done in spare hours at his private observatory. Later he was employed on

scientific commissions and organisation for the Government; and it was not until 1881 that he became Professor in the Royal College of Science. He became Director of the Solar Physics Observatory at South Kensington in 1885, and held the post until the removal of the observatory to Cambridge in 1913.

In the year 1859 Kirchhoff's discovery of the interpretation of the Fraunhofer lines in the sun's spectrum opened up a new sphere of research in astronomical spectroscopy. In England two amateur astronomers became pre-eminent in the new field: Huggins first turned his attention to the stars and nebulæ, Lockyer occupied himself with the sun. It is an interesting example of co-operation that each of them worked in conjunction with a chemist; and the two combinations, Huggins and Miller, Lockyer and Frankland, rivalled one another in the importance of their discoveries during those great years of progress. Lockyer began in 1866 with a small spectroscope attached to his 6-inch equatorial. The same year, in communicating his observations of the spectra of sunspots, he suggested the possibility of detecting the red prominences by means of the spectroscope without the need of a total eclipse. His instrument was then not sufficiently powerful to test this; but by the aid of a Royal Society grant be obtained in 1868 a spectroscope of higher dispersion, and immediately it was received he was able to detect a prominence by the bright lines, which were clearly visible. His discovery was simultaneous with that of Janssen, who was independently led to try the same method through his observations during the total eclipse of that year.

Continuing these researches, Lockyer found that the prominences were projected from an envelope completely surrounding the sun, which he named the chromosphere. Throughout his subsequent work he was impressed with the importance of recognising that a solar or stellar spectrum is a complex effect, the different layers, which vary widely in temperature and constitution, contributing each its quota of absorption or emission. Looking down on the disc of the sun, we see light which has passed through the whole succession of layers from the hot and dense vapours near the photosphere to the outermost rarefied gases. How to disentangle the layers, to trace each absorption to its level, and to discover the changes in constitution and dissociation along the column, is a task which still taxes all our ingenuity. A partial separation was possible at the limb of the sun, where the spectral lines of different characters rise to different heights. This was followed up by studies of the conditions of excitation of these lines in the laboratory. The early recognition of the importance of this clue to the physical conditions prevailing at different levels in the solar and stellar atmospheres is a special feature of the work of Lockyer and his staff at South Kensington. It was in 1881 that Lockyer first made and published his celebrated observation that the iron lines 4924·1 and 5018·6 are greatly enhanced in brightness in

the spark spectrum as compared with the arc. The study of enhanced lines which arose from this observation has now become one of the most important guiding principles in astronomical spectroscopy. The systematic search for this kind of effect in terrestrial spectra seems to have been left in abeyance for many years, and it was not until 1906 that an extensive table of enhanced lines was published from South Kensington. But parallel with, and even earlier than, this discovery Lockyer had been using the same kind of criterion in his theory of dissociation of the elements at high temperatures, relying largely on his interpretation of the chromospheric spectrum. In the *Chemistry of the Sun* (1887) he maintained that the H and K lines were due to a dissociation product of calcium, pointing out that they tended to replace more and more completely the ordinary spectrum as the strength of the electric discharge was increased. Neither his criterion nor his theoretical view of dissociation is sensibly altered when translated in terms of the modern theory of ionisation. This view that the atom is broken up when the element passes into the state necessary for the emission of enhanced lines is now regarded as literally true; an electron has been detached, and the remaining "proto-element," as Lockyer called it, is from the spectroscopic point of view an essentially different atom. Where Lockyer wrote *p*Ca we now write Ca + +, indicating the nature of the change more particularly, but recognising the far-reaching importance of the distinction which he was the first to point out and insist on. If any criticism is to be made on this pioneer work, it is that he attached too exclusive an importance to temperature in breaking up the atom; recent theory has shown that low density is also a very potent factor favourable to ionisation.

To return to his earliest work on prominences, in 1869 he was occupied in studying their spectra, which could now be observed daily, thanks to his and Janssen's discovery. He soon observed the bright yellow line $D_3$, and deducing from its behaviour that it could not be due to any known terrestrial element, he named the new substance *helium*. For nearly thirty years this gas remained unknown except as a constituent of solar and stellar atmospheres, until in 1895 Ramsay found it given off from radio-active minerals. Since then helium has become one of the indispensables of physics, and it is difficult now to recover the outlook of a time when the helium atom was unknown. Besides giving the line $D_3$, helium is the source of important series in the spectra of the nebulæ and hottest stars; in particular, it gives the line 4686, at one time attributed to hydrogen. A unique spectrogram of a helium tube taken at South Kensington showed this line, and in 1905 Lockyer and Baxandall published accurate measurements of its position. But this terrestrial production of the line remained an isolated accident, and the necessary conditions were not again reproduced experimentally until Fowler in 1912 showed how to obtain this and other series lines of helium at will.

In 1887 Lockyer put forward his classification of stellar spectra, according to which the stars formed two series, one of ascending and one of descending temperature. After further laboratory researches on the behaviour of different substances under different conditions of excitation, he published in 1902 a *Catalogue of 470 Brighter Stars classified according to their Chemistry.* Although the existence of two series was in accordance with the theories of Lane and Ritter, which were widely accepted, Lockyer stood alone for twenty years in urging the practical consequence—that it involved a division of the usual Draper sequence of stellar spectra. It was a source of great pleasure to him in later years that the discovery of giant and dwarf stars by Russell and Hertzsprung led to the general acceptance of a scheme corresponding in its chief features with that which he had so long foreseen.

Owing to the researches of Adams, it is now possible to see almost at a glance the distinction between the spectra of the ascending and descending stars; and the criterion depends on the intensities of enhanced lines, which Lockyer had been the pioneer in recognising. It is perhaps disappointing that the details of his classification did not agree more closely with that now accepted, seeing that in regard to the two main points—the existence of widely diffused stars and condensed stars at the same temperature level, and the importance of the study of enhanced lines as a key to physical conditions—he was far in advance of his time. The spectroscopic clue was almost in his hands; but it was through investigations by the older astronomical methods that the solution was actually reached. The reason is not far to seek. The spectroscopic distinction is clear enough as an empirical fact; but it could not have been interpreted with certainty as a criterion of diffuseness without reference to the data of proper motions and parallaxes which have only recently been accumulated. Another difficulty was the extreme faintness of dwarf stars of types K and M, which would be practically unrepresented among the bright spectra that he was studying. He had therefore no opportunity of comparing the ascending and descending stars at those temperature levels where they are most widely separated. The classification formerly accepted placed all these stars on the descending side, whereas actually those available for study were all on the ascending side. Lockyer was not quite radical enough. But although he seems to have erred in leaving Arcturus, for example, as a dwarf star, it does not appear that in any case he wrongly transferred a genuine dwarf star. In examining his classification, one notices particularly the elaborate subdivision of stars generally grouped together as types O and B; he recognised six temperature levels above Sirius compared with three below. Modern opinion is tending to appreciate the soundness of this view; for although stars in these higher groups are rare, it is recognised that they cover a vast range of temperature with wide changes of physical conditions. The actual order of these groups adopted by Lockyer

has received substantial confirmation from the statistical researches of Ludendorff and Herassimovitch.

Perhaps the most significant thing in estimating Lockyer's hypothesis as the forerunner of the modern giant and dwarf theory, is Russell's own statement that he had been deeply impressed with Lockyer's work, and was imbued with these ideas at the time when he found the two series of ascending and descending stars manifested in his statistical studies of absolute magnitude.

With regard to some of Lockyer's more speculative theories, judgment must still be reserved. The chief merit of his meteoritic hypothesis was that it explained the luminosity of the great diffuse nebulæ. It is difficult to believe that these are intensely hot throughout, and Lockyer explained the luminescence as due to continual collisions of meteoric stones. Stars were supposed to be formed by condensations in the nebula; and at these points the increasing frequency of collisions would rapidly convert the whole mass into gas. Some of the spectroscopic evidence which he first adduced in support of this theory has been found to be untenable. But the theory itself is perhaps as plausible as any of the other tentative explanations of this very obscure problem. Lockyer also held that there was an evolution of the elements occurring in the stars, the complex atoms being gradually formed from simpler ones. This was part of his dissociation hypothesis. In the light of the most recent discoveries as to the nuclear structure of the atom, few will disagree with his final statement in *Inorganic Evolution* (1900) that there may be "a gradual building up of physical complexes from similar particles associated with the presence of electricity."

We can do no more than mention Lockyer's archæological researches on the age of Stonehenge and other monuments, leading to results of great interest, though from the nature of the problem somewhat controversial. He was prominent in public life, fighting keenly for a fuller recognition by the Government of the claims of science. With this object he brought about the establishment of the British Science Guild in 1905. But the most conspicuous of these general services to science was his foundation and editorship of *Nature*. It would scarcely be possible to overestimate the importance to scientific progress of this journal, which he edited for fifty years.

On compulsory retirement from South Kensington, Lockyer retired to Sidmouth, where he erected the Hill Observatory. A corporation was formed to carry on the work permanently, and Sir Norman and Lady Lockyer presented the site of $7\frac{1}{2}$ acres. Though the development was interrupted by the war, he lived to see the observatory in full working order, and an organised programme of research actively begun. He died on 1920 August 16.

By his death we lose an astronomer of outstanding fame, whose fifty years of active work links the present stage of astrophysics to its earliest beginnings. He had a rich harvest of immediate and unequivocal discoveries; but we linger now with yet keener interest over his fluctuating contest with the more baffling problems of

stellar physics. Time and progress have cleared away many of the false starts, and have partly reshaped the theories which he held; but we can recognise, better than his contemporaries could, that he was led forward by a vision of principles of evolution which was not an illusion; and now that other fields of research are converging towards his own lonely path, the fulfilment of his vision seems to be drawing near.

He was elected a Fellow of the Society on 1862 March 14, and served on the Council from 1866 to 1872. He resigned his Fellowship in 1897. A. S. E.

Sir Edmund Giles Loder, Bart., was born on 1849 August 7. He was a man of very wide culture and interests. He travelled much and was a keen sportsman, but also a diligent and successful student of various branches of natural science. At Leonardslee, Horsham, he accumulated a fine museum well stocked with specimens of big game and other animals which he had himself shot in various parts of India, America, and Africa, and on the occasion of a short trip to the Sahara secured the fine specimen of a small gazelle now known as *Loder's Gazelle*. In addition he kept a number of interesting and rare animals in a live state. He was also exceedingly interested in trees and horticulture, and possessed unusually fine collections of conifers and rhododendrons, and his rock garden was the model on which that at Kew was based.

It does not appear that he did any systematic observational work in astronomy, at any rate in later years, but he erected an observatory with a refractor of 8 inches aperture, the object glass being by Alvan Clark. He went to the Andaman Islands in 1874 to observe the Transit of Venus, and on an eclipse expedition to Colorado in 1878.

His death occurred on 1920 April 14.

He was elected a Fellow of the Society on 1874 November 14.

Mrs. Fiammetta Wilson was the eldest child of Mr. F. S. Worthington of Lowestoft. The family had been settled in Lowestoft since 1820, and Mr. Worthington took up the practice of medicine and surgery, and succeeded to his father's practice in that town. Mr. Worthington was very devoted to natural science, and after his retirement from practice spent his time in microscopical studies and became an authority on Rotiferæ. He married in 1862 Miss Helen Felicite Till, daughter of Mr. Richard Till, of Clapham.

Mrs. Wilson was born 1864 July 19. Her early education was at home under governesses. She then spent four years in Lausanne, and finally a year at school in Germany. She early showed great facility in acquiring foreign languages, and spoke Italian, French, and German. Always exhibiting a courageous temperament, she was a fearless horsewoman. She played lawn tennis, and danced exceedingly well. All her life she was devoted to animals, and a dog was her constant companion.

After a few years at home she went to Italy to study music, which she did with the thoroughness and power of application which were such marked features of her character.

She was very fond of travelling, and after a year in Italy went to the United States and Canada. When she returned to England she taught for some years at the Guildhall School of Music, and was most successful as a conductor of stringed orchestras, often writing the score herself.

It was not till some time after her marriage with Mr. S. A. Wilson that she became interested in scientific matters, culminating in her attraction to astronomy, through attending a course of lectures on it by Professor A. Fowler about 1910. This became an absorbing interest to her, and she gave up a great deal of her music in order to devote more time to it. Social enjoyments were relinquished so that she might the more fully indulge the passion for astronomy; but her indomitable spirit and energy occasionally led to carelessness of self, which caused suffering.

Another faculty which she possessed in a pronounced degree was that of attracting and pleasing friends.

She invariably made a success of her undertakings. Her musical abilities were considerable. At one period, before astronomy became her dominating study, she wrote a good deal, and her short stories, etc., in magazines were much appreciated.

Mrs. Wilson was justly regarded as the brightest ornament and the most exhilarating presence in the little community of meteoric observers. Not only will her enthusiasm and cheering encouragement be sadly missed, but the cessation of her accurate and numerous observations will cause a void which cannot be filled.

Undismayed by the most unfavourable conditions, and unwearied even by physical weakness, her dauntless spirit often enabled her to gain success where others would have failed. She sometimes watched the heavens for five or six hours, when only a few stars were visible amid the clouds, and her perseverance was often amply rewarded by the detection of fireballs.

Mrs. Wilson was also a keen observer of other phenomena, such as displays of Aurora Borealis, the zodiacal light, comets, etc., and published some interesting and useful data on these appearances.

She had a wooden platform erected in her garden at Totteridge, so that she might get above obstructing trees; and here on her "perch," as she called it, she stood in some of the keenest winds of winter mornings, watching and recording, with wonderful fidelity, the paths of the objects she loved so well.

Throughout her observational work Mrs. Wilson was always actuated by the desire to attain accuracy so far as it was possible. In recording meteors, however, we can only approximate the ideal without attaining it.

Mrs. Wilson invited candid criticism, and even censure if necessary, but the writer (who received all her meteoric work) need hardly say that he invariably found occasion only to praise.

Mrs. Wilson was as prompt as she was exact. One instance may suffice as evidence. On 1914 December 14 she saw a bright meteor at 6.25 p.m., and immediately despatched details by telegram. The writer had seen the same object, and so its real path could be computed within two hours or so of its flashing across the sky; and this constitutes a record for expedition as far as the writer's experience goes.

In the pursuit of observations Mrs. Wilson had to encounter difficulties. Once when watching for meteors on the pier at Looe, on the Cornish coast, a sudden storm arose, and she only saved herself at the expense of a thorough drenching from spray. During the war astute special constables detected the flashlight she used for recording meteors, and severely threatened her with arrest as a German agent. With zeppelins dropping bombs in the neighbourhood, Mrs. Wilson calmly pursued her vigils on several occasions. Falling splinters from shrapnel once made things highly dangerous, but she managed to get good records. At another period it was her custom to watch from the roof of a friend's observatory at Harrow, and narrowly escaped a fall from a ladder. But she regarded these experiences lightly. They certainly brought more of the charm of variety than of the semblance of fear into her ardent quest for meteors.

During the ten years from 1910 to 1920 June she saw more than 10,000 of these objects, and registered the great majority of their paths. Such was her diligence that of about 650 meteors, which were doubly observed and had their real paths computed during the period alluded to, she supplied data with regard to about three-fourths of the total number.

Mrs. Wilson discovered Westphal's comet at its return in 1913, with a Zeiss field-glass, power 8, but Delavan anticipated her by a few days. She wrote an excellent paper, "Clusters and Nebulæ visible with Small Optical Means," for the *B.A.A. Journal* (27, 72, 1916 November), and contributed two papers to the R.A.S., one on large meteors she had observed in 1914, and another on the shower of 1918 January 3 (Quadrantids). She frequently contributed to the *English Mechanic*, *The Chaldæan*, and other English and foreign journals.

She had greatly endeared herself to a wide circle of friends, for she had a sympathetic nature combined with a charmingly vivacious manner. She was very active in encouraging others to enter upon practical astronomical work, and to share the delights which she herself experienced in it.

Of the value of her observations there can be no doubt. The writer frequently found that she was able to supply important records. In the case of the radiant point of the Lyrids, further evidence of its apparent motion was much required, and on 1916 April 26, six nights after the maximum, a bright meteor from it was observed from Bristol; but a duplicate record was needed. A few days later Mrs. Wilson sent in data for the same object, which she had caught between clouds, and the radiant point was accurately

found at 278° + 35°, its motion established, and a missing link added to the chain of evidence.

Mrs. Wilson joined the B.A.A. in 1910, and conducted (with Miss A. Grace Cook) the Meteoric Section of that Association while the Director, the Rev. M. Davidson, was engaged in war duties. She also became a member of the Société Astronomique de France and of the Société d'Astronomie d' Anvers. In 1920 July a letter was received from Harvard appointing her to the "Edward C. Pickering Fellowship for Women" for 1920–21; but she died before the honour could reach her.

For some of the details in this memoir the writer has to express his obligations to Mrs. Wilson's sister, Mrs. Jervase-Hatt.

Mrs. Wilson died on 1920 July 21, two days after her 56th birthday.

She was elected a Fellow of the Society on 1916 January 14.

W. F. D.

Giovanni Celoria was born at Casale Monferrato, near Alessandria, Piedmont, on 1842 January 29. He graduated at the Turin University in 1863, and then decided to adopt an astronomical career; he proceeded to Germany, and studied in succession at Bonn and Berlin. On returning to Italy, he was chosen by Schiaparelli as his assistant at the Brera Observatory, Milan. The bond between the two astronomers became very close; Schiaparelli in his work on double stars referred in terms of warm gratitude to Celoria's great help, and the latter wrote an affectionate appreciation of Schiaparelli after his death in 1910. Schiaparelli retired from the Directorship in 1900, and was succeeded by Celoria, who held the office till 1917, when he retired, but continued to reside at Milan till his death.

Celoria's work covered many branches of astronomy. He was very much interested in the studies of the Herschels on the structure of the universe, and repeated some of their star-gauges, making a star-count with a 4-inch refractor of the zone between Declination 0° and +6°; finding, to his surprise, that near the galactic pole this small instrument showed practically as many stars as the great reflector of Herschel. He deduced the comparative thinness of the star stratum in that direction. His observations also supported the conclusions of Sir John Herschel and (later) of Dr. B. A. Gould that there is a ring of bright stars inclined to the galactic plane at an angle of about 19°. This result has recently been discussed by Dr. Harlow Shapley, who attributes it to a local cluster.

Celoria's contributions to double-star astronomy were specially in the direction of orbit-computation. He also did useful fundamental work, producing a catalogue of the mean positions of 1118 stars.

He took a keen interest in the problem of the moon's secular acceleration. Schiaparelli drew his attention to the "eclipse of Hipparchus," recorded by Cleomedes and Pappus; he thereupon

calculated the elements of all the total eclipses, 139 in number, between the years −332 and −99, and drew a map showing the tracks of those of −309, −241, −229, −187, −128, −115, which all passed within 10° of the Hellespont. His final selection was the eclipse of −309 (Agathocles). Dr. Fotheringham (*M.N.*, 81, 104) has shown that the date −128 is far more probable; but that does not detract from the merit of Celoria's labours, which were much greater than those of recent investigators, since Oppolzer's *Canon of Eclipses* had not yet been published.

Celoria also published a useful memoir on the total eclipses of 1239 June 3 and 1241 October 6. Their tracks lay across populous regions in Europe, and he was able to collect a large number of observations, chiefly of star-visibility, which enabled him to lay down the limits of totality with considerable accuracy: the fact emerged that the regions where star-visibility was reported formed a belt somewhat wider than that of totality. While these eclipses are too recent to be of much use in determining the moon's secular acceleration, they at least form stringent tests which every formula with claims to acceptance must satisfy.

Celoria was keenly interested in geodesy, and occupied the chair of that subject at the Technical College, Milan, from 1875 onwards. He was also the author of several text-books which are in use in the schools and universities of Italy.

He did not neglect his duties as a citizen, being for many years a member of the Milan Town Council, and later receiving the honour of senatorial rank.

He died at Milan on 1920 August 18, at the age of 78.

He was elected an Associate of the Society on 1917 June 8.

A. C. D. C.

Karl Hermann Struve was born at Pulkovo on 1854 October 3. His famous grandfather was at that time Director of the Imperial Observatory, and his father, Otto, an Assistant Astronomer. Otto Struve succeeded to the Directorship in 1862, and remained at Pulkovo till 1889. Thus Hermann Struve's early years were spent at Pulkovo. Later he was sent to school at Viborg, in Finland, going on to the University of Dorpat in 1872. Here he stayed five years, studying mathematics and physics, with a break in 1874, when he accompanied the Russian Transit of Venus Expedition to Port Possiet, on the east coast of Asia. He continued his studies in the Universities of Strassburg, Paris, and Berlin. He returned to Dorpat in 1881, and submitted for his Master's degree a dissertation on Fresnel's interference phenomena. He continued to be interested in optical questions, and a few years later considered the question of telescopic images.

In 1883 he was appointed Adjunct-Astronomer at the Pulkovo Observatory. Beginning with the 15-inch refractor, but after its erection using the 30-inch refractor, he carried out an extensive series of micrometric observations of the satellites of Saturn, Neptune, and Mars. The observations were discussed in a series

of memoirs remarkable for thoroughness, mathematical skill, and lucidity. The most interesting of these researches is that on the satellites of Saturn published in vol. xi. of the *Publications de l'Observatoire Central Nicolas.* From his own series of observations the elements of the different satellites were first derived, and by comparison of earlier observations by Herschel, Lassell, Marth, Bond, Hall, Newcomb, the movements of apses and nodes of the satellites, thus the position of the equator of Saturn and its dynamical oblateness were derived. In particular the librations of Dione and Enceladus and of Tethys and Mimas, resulting from the near commeasurability of their mean motions, were completely elucidated. The masses of the satellites were determined, including those of the very small satellites, Tethys and Mimas. A superior limit was also obtained for the mass of the ring.

From the discussions of his own and earlier observations of the satellites of Mars and of the satellite of Neptune, he determined the movements of their orbits, and thus found the directions of the axes of these planets with accuracy. The position of the axis of Mars is determinable, though not so accurately, by direct observation, but that of Neptune can only be found by the dynamical method. The low declination of Uranus while Hermann Struve was at Pulkovo made it impossible for him to observe its satellites. He discussed the movements of the outer satellites, using all available data, and published the results in 1912. The work of Struve is largely utilised in the *Nautical Almanac* and other ephemerides for the prediction of the positions of the satellites of these four planets. In addition to his work on satellites, he made a considerable number of observations of double stars with the 30-inch refractor.

In 1895 he was appointed Professor at the University of Königsberg and Director of the observatory. Among the work he carried out here may be singled out his micrometric observations of Eros and a short series of observations on the variation of latitude.

In 1904 he was appointed Director of the Berlin Observatory in succession to Förster. He carried through the transference of the observatory to Babelsberg, which was completed in the summer of 1913. Several new instruments were installed, including a large refractor with an object glass of 65 cms. and a new transit circle and an astrographic telescope. An extensive programme of work was designed, including photo-electric work and determination of refraction. Professor Struve himself continued observations on the satellites of Saturn with the great refractor.

The value of Struve's work was recognised in France by the award of the Damoiseau prize and in England by the award of the Gold Medal of the Royal Astronomical Society. As noted by the President, this is the only case in which the medal has been awarded to three generations of the same family. Professor Struve had many friends among the astronomers of Europe and America. In the few years between 1910 and 1914 he visited England,

France, and the United States, and in the summer of 1913 a number of European and American astronomers had the pleasure of visiting the new observatory at Babelsberg. Personally, Struve was of a modest and unassuming disposition; his tastes were essentially those of a scholar; his researches reveal observational and mathematical skill and also an artistic pleasure in presenting his results in clear and simple form.

He died on 1920 August 12.

He was elected an Associate on 1892 November 11.

F. W. D.

## Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

### *Royal Observatory, Greenwich.*
### (*Director, Sir Frank Dyson, Astronomer Royal.*)

*Transit Circle.*—The revival of observing which began last year has continued, and 8966 transits have been observed. One-third of the observations were made in February and March; the latter part of the year, with the exception of October, has been very cloudy. Good progress has been made with the catalogue of Backlund-Hough stars. All observations are reduced to apparent place up to 1920 December 31.

The sun was observed on 140 days and the moon on 109 days.

*Altazimuth.*—The moon was observed on 1 night in the meridian and on 22 nights out of the meridian. The mean error in right ascension of the *Nautical Almanac* is $-0^s{\cdot}94$, and of the *Connaissance des Temps* (Delaunay) $-0^s{\cdot}25$. The corresponding quantities found from the transit circle are $-0^s{\cdot}88$ and $-0^s{\cdot}26$. The error of the *Connaissance des Temps* is slightly less than in the four preceding years, when it remained steadily at $-0^s{\cdot}28$.

*Cookson Floating Telescope.*—During the year 201 plates have been taken. As usual, there is difficulty in getting sufficient plates in the winter months. The measurement and reduction of the plates is well advanced, and the variation of latitude for 1920 will be communicated to the Society in March.

*Occultations.*—Five disappearances of stars at the moon's dark limb were observed by one or more observers.

*28-inch Refractor.*—The repair and re-erection of the equatorial mounting was completed by Messrs. Cooke in October. The new pivots and ball-bearings work very satisfactorily, and the instrument moves with the greatest ease. Observations were recommenced on October 25, and 70 observations of double stars have been made on 15 nights. The instrument was used on several nights in November by Commander Ainslie, Major Hepburn, and Captain Steavenson for the study of Saturn's ring about the time of the transit of its plane through the earth. The results were communicated to the Society in December.

*Thompson Equatorial.*—With the 26-inch refractor 338 plates were taken in the early morning and 340 plates in the evening for parallax determination. During the year 619 plates have been

measured. The parallaxes of 49 stars have been communicated to the Society. The new star in Cygnus discovered by Mr. Denning was observed by Mr. Luyten, who exposed 66 plates for magnitude determinations. The results were communicated to the Society in November.

The 30-inch reflector has been used for the determination of effective wave-lengths of stars. For the purpose a parallel wire grating on the model of that used by Professor Hertzsprung at Mount Wilson was constructed consisting of parallel wires of $1^{mm}\cdot4$ diameter placed $1^{mm}\cdot4$ apart. As a preliminary trial 21 photographs with two exposures of 15 minutes each have been taken of fields within three degrees of the North Pole. Most of the plates have been measured and the results tabulated. The effective wave-lengths are obtained of all stars down to $11^{m}\cdot0$ (photographic), and a considerable number below that limit. The agreement of different plates with one another is satisfactory. A discussion of the results is being made for the area within three degrees of the pole, and if the results are of sufficient value observations will be continued over the whole of the Greenwich Astrographic Zone.

*Astrographic Equatorial.*—Parts of the driving mechanism which were badly worn were repaired by Sir H. Grubb & Sons. The instrument, which now works very satisfactorily, was brought into use in June. Photographs have been taken with a grating with an interval of $2^{m}\cdot83$ for the purpose of checking the Harvard Polar Sequence of magnitudes from $5^{m}\cdot0$ to $10^{m}\cdot0$. In all 57 photographs of 14 stars between these magnitudes have been taken. More than half the plates have been measured, and the provisional results appear to agree closely with those obtained at Mount Wilson. In addition 14 plates with exposures of 15 to 30 minutes have be taken of the polar area for a determination with the astrographic telescope of the magnitudes from $10^{m}\cdot0$ to $14^{m}\cdot0$.

*Photoheliograph.*—Photographs of the sun were obtained on 231 days, of which some 15 were days of bad definition. At the Cape observatory photographs were obtained on 335 days, leaving for the year 7 days unrepresented by photographs from the combined record of the two observatories; of these, however, 6 are available from the daily series taken at Kodaikánal.

The first eight months of the year were devoted largely to the measurement of photographs, and the arrears have been brought up from 1917 December 17 to 1919 June 28. The measures have been fully reduced up to 1917 October 3, and in part to December 31 of that year.

A preliminary reduction of 36 photographs distributed equally throughout 1920 shows that the mean daily spot-area, in millionths of the sun's visible hemisphere, was about 700, as compared with 900 for 1919 and 1450 for 1917. The general sun-spot activity was decidedly lower than in 1919, but the presence of four or five very large groups was largely responsible for the high mean daily value.

*Wireless Time-Signals.*—The morning signals from the Eiffel

Tower, Nancy, and the $17^h$ signal from Annapolis have been regularly observed. The signals from Lyons have been observed regularly from April to October, and occasionally at other times. Darien has been observed when possible, and many unsuccessful attempts have been made to observe Honolulu. The special rhythmic signals sent from Lyons by the courtesy of Gen. Ferrié for experimental work on Australian longitudes have also been observed. Many modifications in detail have been made in the installation, resulting in a considerable improvement in the reception of signals. A siphon recorder has been brought into use for recording strong signals sent by spark-transmitters or continuous wave if generated by high-frequency alternator.

*Franklin-Adams Charts.* — In conjunction with the Royal Astronomical Society, a second series of prints of these charts is being issued. Prints have been made of about one-third of the charts.

*Printing.*—Very satisfactory progress has been made during the year in overtaking the arrears of printing. The volume for 1915 has been issued, and the printing of the volume for 1916 is complete except for the photoheliograph and meteorological sections. The catalogue for 1910 is being distributed. The variation of latitude results for 1911–1918 have been printed, and are being bound. The catalogue of double stars is about half printed, and vol. iv. of the astrographic results giving proper motions and magnitudes is at the same stage.

*Royal Observatory, Cape of Good Hope.*
(*Director, Mr. S. S. Hough, H.M. Astronomer.*)

The year 1920 marks a special epoch in the history of the observatory, being the centenary year of its foundation by Order in Council.

*Transit-Circles.*—All observations have been made with the Reversible Transit-Circle, the programme of the previous years, commencing with 1918, having been continued. During the year 6922 transits and 6860 observations of zenith distance were obtained.

*Heliometer.*—This instrument was used on 26 nights for the observation of the major planets at the time of opposition, in continuation of a programme originally commenced in 1897.

*Victoria Telescope and Astrophysical Laboratory.* — The Victoria telescope has been in regular use for the determination of stellar radial velocities, and a programme of observations of spectroscopic binaries is being gradually introduced as the previous working list is approaching completion. The telescope has been in use on 175 nights; 260 spectrograms have been secured and 348 measured, many of these in duplicate. The four-prism spectrograph and short camera have been employed throughout the observations.

In the laboratory the four-prism Hilger Laboratory spectrograph has been employed on work connected with the enhanced line spectra of nitrogen, carbon, and oxygen, with a view to the elucidation of the spectra of Novæ.

*Astrographic Telescope.*—At the request of Professor Turner, a series of plates, 186 in number, including repetitions, centred on the zone of declination $-22°$ have been secured. Of these 48 have already been forwarded to Oxford for measurement.

In addition the following miscellaneous plates have been obtained:—

| | | | | | |
|---|---|---|---|---|---|
| South polar region (for standard stellar magnitudes): | 9 | plates | with | 118 | exposures. |
| Chart plates (repeated) | 2 | ,, | ,, | 6 | ,, |
| Achilles region | 8 | ,, | ,, | 14 | ,, |
| Comet Skjellerup (1920) | 6 | ,, | ,, | 6 | ,, |
| South Pole trail | 2 | ,, | | | |
| Adjustments | 9 | ,, | | | |

*Photoheliograph.*—687 negatives of the sun have been secured on 333 days during the year.

*Occultations.*—Twenty separate phenomena of occultations of stars by the moon have been observed, viz.:—

| | |
|---|---|
| Disappearances at dark limb . . | 12 |
| Reappearances ,, ,, ,, . . | 8 |

*Variable Stars.*—Observations of variable stars have been continued by Messrs. Long and Skjellerup. Some 119 stars have been under observation, and 473 determinations of visual magnitude have been made.

*Seismograph.*—A new seismograph of the Milne-Shaw type has been supplied in lieu of the earlier Milne instrument. A special building has been erected for its accommodation. Owing to delay in the completion of this building the instrument, which reached the observatory early in the year, was not mounted until September 20. Some difficulties in its use were experienced at first, chiefly in connection with the performance of the driving clock. These appear now to have been successfully overcome.

*Current Reductions.*—All meridian observations up to 1920 December 3 have been reduced so as to exhibit apparent places. The reductions to mean place 1920 have been computed to 1920 March 15, and the mean places formed to 1919 September 8.

The MS. of the ledgers of meridian observations 1912–17 has been sent to press, and proof-sheets passed up to 12 hours.

Proof-sheets of a catalogue of 1846 stars based on observations during the years 1912–16 have been passed through the press during the year.

Copy for press of a catalogue of 20,843 stars, including the standard stars, together with all stars brighter than the ninth magnitude, in the "Cape Astrographic Zones" ($-40°$ to $-52°$) has been completed.

Progress in the printing of the "Cape Astrographic Zones" has been slow on account of delay on the part of the printers. During the year proof-sheets have been passed for the zone $-45°$ declination from 6 hours to $13\frac{1}{2}$ hours.

Considerable progress has been made with arrears of reductions of heliometer observations of the major planets during the years 1911–19. The reductions of the observations for 1911–12 are now practically completed, while several parts of the remainder of the work are already in an advanced stage.

The following parts of the *Cape Annals* have been sent to press during the year:—

Vol. viii. part v., containing the "Results of Meridian Observations of the Sun, Mercury, and Venus during the years 1912–16."

Vol. x. part v., containing "Radial Velocities of 120 Southern Stars."

Vol. xi. part iv., containing "A Discussion of a Series of Meridian Observations of Circumpolar Stars made in 1917."

Vol. xi. part v., containing "Ephemerides of 99 Southern Circumpolar Stars derived from Observations 1830–1917."

The MS. of vol. x. part vi., containing "The Variable Orbit of the Spectroscopic Binary 42 Capricorni," has been completed for press.

Papers by Dr. Halm "On the Systematic Motions of Stars derived from Radial Velocities," and by Dr. Lunt "On the Spectra of Nova Aquilæ," have been communicated to the Royal Astronomical Society.

Additional papers by Dr. Halm

(*a*) "On the Relations between the Masses, Mean Densities, and Luminosities of the Stars";

(*b*) "On the Relation between the Velocities of the Stars and their Masses,"

have been prepared for publication.

*Miscellaneous.*—In connection with the wireless installation, originally erected with a view to checking the daily time signals emitted from the Slangkop station, a ten-valve amplifier has been supplied. By this means and by an extension of the aerial it was hoped that reception of time signals from some of the more distant stations, with a view to a comparison of time determinations with other observatories or field stations, would be rendered possible. While the sensitiveness of the apparatus has been vastly improved, the hopes of picking up high-power distant stations emitting time signals have not yet been realised.

The time-signal service and meteorological observations have been continued as in previous years.

*Royal Observatory, Cape of Good Hope:*
1921 *January* 6.

*Royal Observatory, Edinburgh.*
(*Director, Professor R. A. Sampson, F.R.S., Astronomer Royal for Scotland.*)

The work of the Transit Circle has been directed, as in recent years, to questions of time determination and time keeping. In this connection material changes have been made in the clock Synchronome II.; the crutch is removed and the pendulum is therefore entirely free at the ends of its swing. The results are promising. The clock King 2, with chronometer escapement and Mr. King's remontoire applied at the foot of the pendulum, has been fitted with a connection to the chronograph, to allow more stringent examination of its time keeping. The case of this clock is not sealed, and it carries Robinson's compensating barometer to correct for changes in air-pressure.

A great deal of work has been spent on efforts to make the driving of the 24-inch reflector satisfactory. It is much improved but still uncertain.

A fine photographic lens of 4-inch aperture and 24-inch focus was secured from the Disposals Board, and for small-scale pictures of wide fields supplies very beautiful results. It is mounted alongside the 15-inch refractor in the east dome.

A photometer has been constructed for estimating stellar images, upon Koch's principle, with two photo-electric cells, one receiving the beam through a pinhole, obscured by the image, and the other a balancing cell receiving the same beam under constant circumstances. After some trials and changes the instrument seems to be very satisfactory.

A series of plates were taken for the sun's rotation with the solar spectroscope. The measures of these and earlier plates obtained are well advanced.

Calculation of the plate constants for the Perth zone of the *Astrographic Catalogue* are near completion. The revision of magnitudes undertaken upon Mr. Cooke's method has been interrupted owing to the breakdown of the eyepiece comparison scale provided.

Regular observations have been continued as routine in seismology, meteorology, and atmospheric electricity.

The membership of the observatory staff is unchanged.

*Cambridge Observatory.*
(*Director, Professor A. S. Eddington, F.R.S.*)

The meridian observations for the *Cambridge Zodiacal Catalogue* have been completely reduced to the equinox 1900·0, and the results are now being examined for discordant observations. The catalogue will contain the places of about 2600 stars based on more than 14,000 observations.

The study of the change of the effective wave-lengths of

δ Cephei during its light variations has been resumed, and plates on 15 nights have been obtained with the Sheepshanks Equatorial. The measurement of the plates is near completion.

The photographic magnitudes and effective wave-lengths of Nova Cygni (1920) have been reduced from observations made on 13 nights: the results have been communicated to the Society.

To determine proper motions in the Pleiades, two plates of the field were taken in 1920 February with the photographic plate placed film side outwards; these were compared with plates taken in the usual way in 1906 by superposition film to film. From a preliminary discussion of the plates this method of investigation of proper motions appears promising, and three further plates of three hours' exposure have recently been obtained. The determination of the proper motions is now in progress.

For future needs it is proposed to obtain plates of long exposure on several of Kapteyn's selected areas: three plates have so far been obtained.

*Solar Physics Observatory, Cambridge University.*
*(Director, Professor H. F. Newall, F.R.S.)*

*Spectroheliograph.*—Photographs of the sun's disc in $K_{2-3}$ light have been obtained on 85 days (previous year, 86), and photographs of the prominences at the limb on 61 days (previous year, 75).

The general activity of the sun has decreased during the year, but there were very large disturbances in February, March, April, and September, after intervals of moderate activity.

For the year 1919 October 1–1920 September 30, the Director of the Kodaikánal Observatory has sent 333 spectroheliograms showing the solar disc in $K_{2-3}$ light.

The photographic enlargements of spectroheliograms have been now brought up to date.

The examination of the Kodaikánal photographs has been continued. The systematic orientation is complete from 1915, and the plates from 1906–1914 are now being dealt with. The work is in the charge of Mr. Butler.

*Photoheliograms.*—Daily photographs taken with the photoheliograph at Dehra Dûn have been received as in previous years.

*Study of Sun-spot Records.*—The study of the irregular proper motions of sun-spots has been continued by the Director with the assistance of his private secretary, Mrs. Beech, in relation to the cycles 1879–1889 and 1889–1901, and by Mr. Moss in relation to the cycle 1902–1913.

*Stellar Spectra.*—The account of the investigation of the Cambridge and Allegheny spectrograms of *Nova Geminorum II.* has been published, and distributed as part i. of vol. iv. of the *Annals of the Solar Physics Observatory.* A short note by Mr. Stratton on the main results was published in the *Monthly Notices*, **80**, 540.

A number of spectrograms of *Nova Cygni III.*, the new star discovered on August 20 by Mr. W. F. Denning, were secured by the Director and Mr. Stratton. A preliminary note on the measurements and reduction has appeared in the *Monthly Notices*, 81, 50.

The laborious measurement, reduction, and discussion of the 43 spectra of *Nova Aquilæ III.*, kindly sent to the observatory by Dr. Plaskett, Victoria, B.C., has been continued by Mr. Baxandall. A note by him "On the Presence of Absorption Lines of Nitrogen and Oxygen in the Spectra of *Nova Aquilæ III.*" was published in the *Monthly Notices*, 81, 66.

*Radiative Equilibrium in Stellar Masses.*—An investigation of some points in the theory of radiative equilibrium in stellar atmospheres is being carried out by Mr. Milne.

*Investigations in Atmospheric Electricity.*—The results of researches in atmospheric electricity, which have extended over several years, were discussed by Mr. C. T. R. Wilson in a paper communicated to the Royal Society in March, and published in the *Philosophical Transactions*, A, 221, 73–115. During the past summer several thunderstorms were studied by the methods described in the paper above mentioned; and experiments were also made to investigate the magnitude of the vertical electric current over grass under applied electric fields of the same order of magnitudes as those encountered in thunderstorms. Mr. Wilson has also been engaged in developing his cloud-track method of studying ionising radiations.

*Staff.*—In October E. A. Milne, B.A., Fellow of Trinity College, joined the staff as Assistant Director. Mr. W. E. Rolston resigned his post on the staff in September, and is still with the Army of Occupation at Cologne.

*Dunsink Observatory.* (*Director, Professor H. C. Plummer, F.R.S., Royal Astronomer of Ireland.*)

The results of 38 fine nights, of which nearly half fell near full moon, hardly deserve recording. On these nights and in other brief intervals 128 plates were obtained with the Roberts reflector, and 148 plates were measured and reduced. Work has been done on the variables Y Aurigæ, SY and UU Cassiopeiæ, and RR Leonis. But none of these investigations could be completed before the end of the year.

For the time service to Dublin and for the general purposes of the observatory, clock error has been determined with the meridian circle on 86 nights. The mean time clock is also compared daily with the ordinary Paris time signals.

The Royal Commission on the University of Dublin (Trinity College) visited the observatory in April. Their subsequent recommendations chiefly refer to the salaries of the staff, in which there has been no change during the year.

*Hill Observatory, Salcombe Regis, Sidmouth.*
(*Director, Major William J. S. Lockyer, M.A., Ph.D.*)

On August 16 the observatory lost its distinguished Director, Sir Norman Lockyer, and he was buried on August 21 at Salcombe Regis, within a mile of the observatory which he founded and fostered.

The usual routine of photographing the spectra of stars with the 12-inch McClean prismatic camera has been continued, and these stars have been classified according to the scheme of increasing and decreasing temperatures.

Preliminary work of determining the parallaxes of stars of certain spectral types according to the relative intensities of certain lines in their spectra has been carried out, and a number of special photographs taken for this purpose. The results so far seem very promising.

In all 185 plates have been obtained, many of which contain more than one star for classification.

Observations of Nova Cygni III. were begun on August 22, and numerous magnitude determinations were made in addition to 69 photographs of the spectra. Several photographs of the spectra of planetary nebulæ and certain stars were taken for comparison purposes. A paper on this subject was communicated to the Society, and a second one is in hand.

The 9-inch prismatic camera, mounted on the Kensington 10-inch refractor, is being prepared for use, the second prism of 7 inches aperture and 40° angle having been taken off it in preparation for returning it to the Eclipse Committee.

All the instruments and apparatus are in good working order, and the library has been greatly enriched by gifts during the past year, Sir Norman Lockyer having presented the whole of his astronomical library. Bookbinding has been taken seriously in hand, and is making good progress.

During six weeks of the summer months Mr. W. B. Rimmer worked as a research student at the observatory.

The Annual General Meeting of the Hill Observatory Corporation took place on June 28.

*Liverpool Observatory, Bidston.*
(*Director, Mr. W. E. Plummer.*)

The usual routine of observations has been continued.

*Radcliffe Observatory, Oxford.*
(*Director, Dr. A. A. Rambaut, F.R.S., Radcliffe Observer.*)

The programme of work with the 24–inch photographic refractor on Kapteyn's "Selected Areas" was continued during the year. Thirty-two proper motion photographs were secured, twelve

on Kapteyn's original plan and twenty control plates. The latter have all been taken with the film at the back for comparison with those obtained and developed ten years previously.

The plates taken on Kapteyn's plan continue to prove quite satisfactory, being but little impaired by being stored for ten years. The second pairs of images are as good for measurement as those of the earlier exposures. It is necessary to exercise extreme caution in exposing these plates for the second series to avoid the risk of interruption by cloud, which might render the whole photograph valueless as a proper motion plate.

The 10-inch Barclay refractor has been used for observations of *Nova Cygni*. It has also been requisitioned for visitors to the Observatory on several nights.

Occasional observations have been made with the Transit-Circle, chiefly for the determination of instrumental corrections. When attempting to take Level observations on December 16 anomalous movements of the reflected image of the wires were observed. These were afterwards proved to have been caused by the great seismic disturbance of that date.

The new star in Cygnus, discovered by Denning on August 20, was first observed here on the 22nd. Estimations of magnitude with the naked eye or with binoculars were secured on 23 nights. Since September 28 the magnitudes have been obtained with the finder or with the 10-inch objective of the Barclay refractor on 34 nights, and the character of the image of the new star in the latter has been recorded on several occasions. A paper on the subject has been communicated to the Society, which has appeared in *M.N.*, 81, 52.

The staff of the Observatory was completed towards the end of the year. It is now constituted as follows:—

| | | |
|---|---|---|
| Mr. William H. Robinson. | First Assistant, from | 1920 July 1. |
| Mr. H. G. Scott Barrett . | Second Assistant, ,, | ,, ,, |
| Mr. James G. Balk . . | Third Assistant, ,, | ,, Oct. 1. |
| Ernest G. Shirley . . | Computer, ,, | ,, Sept. 27. |

Vol. lii., part iv., of the *Radcliffe Observations*, containing the results of meteorological observations made during the year 1919, was printed, and a limited number of copies distributed in the usual manner.

### *University Observatory, Oxford.*
### (*Director, Professor H. H. Turner, F.R.S.*)

Volume v., zone +60°, of the *Vatican Astrographic Catalogue* is completely printed, and will be distributed shortly. The reductions of zone +56° are completed, and those of +55°, the last zone, are proceeding.

Mr. Hough has fulfilled his promise of sending plates in zone −22°, so that 57 satisfactory plates in all have now been measured.

Meanwhile Hyderabad Observatory is also diligently measuring this zone, so that a check on possible systematic differences between plates taken in the two hemispheres is being provided. The next zone north of Oxford was assigned to Potsdam, and 32 plates are required to complete zone $+32°$: 10 of these have been measured and reduced.

The plate of the $h$ and $\chi$ Persei clusters was measured by the Rev. F. H. Macklin, S.J., as an investigation for a research degree: he is preparing some interesting results for publication.

The suggested period of about 240 years was followed in the long series of tree records, with the result that there seem to be two periods of about 284 and 303 years, with their harmonics. Meanwhile Dr. Fotheringham has followed up his investigation on the moon's motions in the past by an analysis of solar eclipses, and appears to have arrived successfully at a definitive solution of this long-standing puzzle.

The seismological work has been carried on during the year under some difficulties, as possession of the house purchased for the purpose was not obtainable. There was a very large earthquake on December 16, the location of which for some days was rendered doubtful by misleading news from America, but was ultimately identified in Northern China (35°·5 N., 106°·5 E.).

Mr. E. F. Sawyer kindly sent some early observations of W Cygni, which were analysed by Miss Blagg and the Director; the independent periods of 129·6 and 243 days were fully confirmed, as also the abrupt changes at intervals, but the waxing of short period and waning of the long is not confirmed. Curiously enough the inferences from this suggested waxing and waning—viz. that the periods of Group II. stars are decreasing and those of Group I. are increasing—seem to be justified by numerous examples, to which exceptions are very rare, if they exist at all.

Barnard's observations of variable No. 33 in the cluster M5 were further analysed, and led to the suggestion that his comparison star $k$ is also variable in about 12 hours.

*The Coats Observatory, Paisley.*
*(Principal M'Lean, B.Sc., C.E., Convener.)*

The number of visitors to the observatory during the year was 383, and included members of the West of Scotland Branch of the British Astronomical Association and similarly interested bodies.

The observer, Mr. Donald M'Lean, F.R.A.S., made a determination of the position of Nova Cygni.

The Milne seismograph recorded 46 distinct earthquakes.

The phenomenal rainstorm of August 17 was the heaviest registered at the observatory since it was opened in 1883. Between 10 a.m. on 17th and 10 a.m. on 18th no less than 3·103 inches were registered.

*Imperial College, South Kensington.*
*(Professor A. Fowler, F.R.S.)*

As in former years, the astronomical instruments were chiefly used for the instruction of students.

Experimental work in the spectroscopic laboratory was continued in several directions. Particulars of additional enhanced lines of nitrogen, which are of importance in connection with novæ and Wolf-Rayet stars, have been communicated to the Society. Preliminary work with the new vacuum grating-spectrograph absorbed a great deal of time, but the initial difficulties have now been largely overcome, and the work on the series lines of silicon and other elements is being continued. Mr. S. Datta, of Calcutta University, made a comparative study of the band spectra of the alkaline-earth fluorides, and has traced relations of considerable interest among them. Dr. M. N. Saha, also of Calcutta University, joined the laboratory in October, and has continued his work on the theory of temperature ionisation in relation to solar and stellar spectra. The demonstrator, Mr. H. Dingle, was occupied with an extensive revision of the series lines in the spectrum of mercury. Another investigation in progress refers to large displacements of certain lines of nitrogen which occur under some conditions of excitation in vacuum tubes.

A considerable amount of time was occupied by work connected with the International Astronomical Union, of which Professor Fowler is General Secretary.

*Stonyhurst College Observatory.*
*(Director, Rev. A. L. Cortie, S.J.)*

The observatory has sustained a great loss by the death of Brother W. M'Keon, S.J., on May 18 last. He had been attached to the staff since the year 1878, and for forty years had charge of the solar observations. He was an expert in the delineation of sun-spots and faculæ, a painstaking, conscientious, and accurate observer. Many examples of his beautiful drawings have appeared in the Society's publications. He accompanied Father Cortie as his assistant in the total solar eclipse expedition of 1911 to the Tonga Islands.

In addition to the Director, the present staff of the observatory consists of Father J. Rowland, S.J., chief assistant, and the Rev. H. Macklin, S.J., who joined the staff in 1921 January.

The routine observations in meteorology, terrestrial magnetism, and seismology have been maintained.

Observations of the sun's surface were made on 207 days, and include 205 drawings on 202 days, and notes on uncompleted drawings on 5 other days. Of these drawings 189 on 188 days show all spots and faculæ visible, and the remaining 16 are

complete for the spots, but are deficient in the record of the faculæ. The mean daily disc-area of the spots (in units $\frac{1}{5000}$ of the visible surface) was 4·05.

The sun-spot activity, which had revived in 1919, as compared with 1918, the disc-areas of the spots being 8·35 and 7·90 respectively, shows a considerable decline. But the revival of the first eight months of 1919 was renewed in the earlier months of 1920. The most disturbed area was that in mean latitude − 6·0°, extending in longitude from 114° to 150°, which was active from 1919 December 27 to 1920 May 11. The very great spots of January 28 (18·3 units) and of March 23 (25·8 units) formed part of the disturbance. A full account of this great group and of the accompanying violent magnetic storm appeared in *M.N.*, 80, 574.

The same region was again disturbed, when a large group (lat. − 11·6°, long. 130·1°) crossed the sun's disc from September 21 to October 4, attaining an area of 9·4 units on September 26. Two other noteworthy groups appeared, the one at the beginning of September (lat. − 14·8°, long. 108·9°), its disc-area on September 6 being 10·0 units; the other from October 31 to November 11 (lat. − 10·9°, long. 346·4°), its maximum disc-area being 11·2 units on November 5. The greater activity therefore still persisted in the sun's S. hemisphere.

Four spotless days were recorded, September 17–20, the first which have occurred since 1916 August 26. The appearance also of faint polar faculæ heralds the approach of a sun-spot minimum.

A comparison of drawings of solar faculæ and of spectroheliograms of calcium flocculi was made, and the results were communicated to the British Association at its meeting at Cardiff (*The Observatory*, 1920 November).

A satisfactory series of spectrograms of Nova Cygni III. was obtained, chiefly with the Whitelow prismatic camera. Preliminary results from measurements have been presented to the Society (*M.N.*, 81, 57). The Hilger direct-vision spectrograph has been readjusted, and spectrograms of some of the brighter stars have been secured in the red end, to supplement our collection of spectrograms in the more refrangible region of the spectrum.

### *Mr. A. A. Buss's Observatory, Chorlton-cum-Hardy.*

The year under review, owing to persistently unfavourable meteorological conditions, afforded only 84 dates for solar observations, which were all made with the 6-inch Simms O.G., in combination with a polarizing eye-piece for purely telescopic scrutiny, and a Rowland solar spectroscope for the observation of prominences, disc eruptions, dark $H_\alpha$ flocculi, etc. etc. The sun's activity continued to decline on the whole, yet there were

several striking secondary revivals, particularly during the early spring of the year, and all the phenomena noted in previous records were again observed in 1920.

It is worthy of special notice that there were many instances in which considerable spot-outbreaks originating in the eastern hemisphere developed quickly into important displays of huge dimensions, thus giving the spotted area of the western hemisphere a large excess over that of the eastern one; and precisely the same excess was observed in the case of prominences. It may of course be a passing characteristic, but it also affords proof that an excess in these respects of the eastern over the western hemisphere is far from being permanent and exclusive.

The event of the year was the fine outbreak in March, a magnificent compound-group being intersected during one or two days by a striking luminous photospheric tongue; the spectroscope indicated rotary motion of the tongue around its longitudinal axis of propagation. The great activity of this group was further indicated by the fine auroral display of March 22–23. Its presence was noticed immediately at dusk, the green line being exceptionally vivid throughout the display, which was observed from 9 p.m. till 2 a.m. During its later stages it was remarkable to witness the extraordinarily great general illumination of the sky, which at intervals was suffused suddenly with such brightness as to permit the reading of newspaper print. A further exceptional feature of this aurora was the extraordinary velocity and deliberateness with which groups of adjacent coruscations, or streamers, moved across the whole sky from east to west in a few seconds.

### *Mr. C. F. Butterworth's Observatory, Waterloo, Poynton, Cheshire.*

Working conditions were below the average of eleven years. Observation was possible on 221 nights, on 171 of which a full night's work was done, and first-class conditions prevailed throughout darkness on 83 nights. 3500 estimates of magnitude of 40 variable stars of the B.A.A. list, and 2 Novæ, and 1100 of 26 "extra" stars, were sent to the Director of the Variable Star Section. Over 200 results were discarded, half for bad conditions, and half rejections, as customary, when only records by Averted Vision were entered in diary. From April to August, both inclusive, photographic work was much hindered by bad skies, but earlier and later exposures were continued on $\gamma$ Cassiopeiæ, and a short series in August-September on Nova Cygni III., all with the $6\frac{1}{3}$-inch camera on panchromatic plates. A camera of $8\frac{1}{2}$-inch, with prism of $12\frac{1}{2}°$, has been mounted together with the 15-inch Cope mirror on the same equatorial, recently overhauled; with modifications of the drive this is expected to be suitable for exposures up to 60 minutes.

*Wolsingham Observatory.* (*Rev. T. E. Espin.*)

The search for new double stars has been continued with the 17¼-inch and 24-inch in the selected zones, together with micrometrical measures of some neglected objects, and the results communicated to the Society. 192 comparisons of the magnitudes of 51 stars were made, and the variable star B.D. +39°·3476 has been observed on 38 nights by Mr. Espin. Mr. Milburn has made 260 comparisons of the magnitude of 44 stars, and has observed B.D. +39°·3476 on 75 nights and Nova Cygni III. on 27 nights. In the autumn a photographic star detector, made by Mr. Whittle of Liverpool, under our direction, was installed, and 34 plates have been taken of various parts of the sky by Mr. Milburn. The weather has unfortunately been very unfavourable during the year.

*Mr. A. M. Newbegin's Observatory, Sutton, Surrey.*

Observations of solar prominences in 1920 were resumed on February 17, and during the year 111 complete records were made.

The results will be published in detail in due course.

A 3-inch transit by Troughton & Simms has been added to the equipment for time observations.

*Rousdon Observatory, Devon.*
(*Sir Wilfrid Peek's; Mr. C. Grover, Observer in Charge.*)

The observatory and instruments are maintained in good working order, and observations have been made on 183 nights. 431 magnitudes of the long-period variable stars have been recorded, making a total of 14,994 magnitudes during thirty-five years' continuous observation with the 6·4-inch Merz achromatic telescope, equatorially mounted by Cooke. During this period 533 maxima and 366 minima have been observed.

*Rev. T. E. R. Phillips's Observatory, Headley, Epsom.*

Observations were continued on the same lines as in previous years.

The Coleman Equatorial belonging to the Society was used for the measurement of double stars, and, together with the 12¼-inch reflector, for systematic work on the planets.

The observations of Jupiter are described in the Council note on the planets.

The opposition of Mars was not very well observed, owing mainly to the long continuance of poor seeing conditions, but drawings and other observations were obtained whenever possible.

Saturn was frequently observed in the autumn mornings about the time of the disappearance of the ring. The latter was plainly visible on November 6, the day previous to the passage of its plane through the earth, but nothing was seen of it again until November 20.

The total lunar eclipse on May 2 was observed under moderately favourable conditions, but clouds and rain rendered observations of the occultation of Lal. 20654 by Saturn on March 14 impossible.

At the beginning of the year the Matthew Transit (lent by the Society) was erected, and in the autumn a wireless installation was added to the equipment, Mr. P. M. Ryves kindly carrying out the work.

### *Mr. J. H. Reynolds' Observatory, Harborne.*

During the year the 30-inch Common mirror (used at Helwân up to 1914) was installed in the reflector mounting. The reflector and photomicrometer have been employed chiefly on nebular photometric work, and some of the results have been communicated to the Society.

### *The Dominion Observatory, Ottawa, Canada.*
### (*Director, Dr. Otto Klotz.*)

*Meridian Work and Time Service.*—Observations with the meridian circle were obtained on 137 nights. The observations were, as heretofore, divided between the programme of latitude stars under observation, and transit observations for determination of clock error and measurements of longitude.

The division errors of the single degree marks of both graduated circles were measured; for this purpose an auxiliary pair of microscopes was used, mounted successively at 45°, 36°, and 44° from one of the fixed pairs. The observations yielded also a determination of flexure of the circles, which was found to be appreciable. The number of pointings was approximately 20,000.

Field observations for latitude and longitude were carried out at five points in British Columbia at the request of the provincial government; the longitudes were determined directly from Ottawa.

The time service has been maintained as in previous years. There are 10 secondary master-clocks synchronised continuously from the observatory; these in turn control 390 clocks and dials of various kinds, including two tower-clocks.

Relays beating seconds are maintained in three offices in the city, one private master-clock is connected with the system and corrected hourly by a special signal, time-signals are sent out by telegraph and telephone, and the time is recorded on the various seismographs at the observatory.

Some experimental work has been done on the reception and

registration of wireless time-signals, more especially with reference to the possibility of systematic errors in chronographic registration.

*Astrophysics.*—During the year 1920 the 15-inch equatorial has been employed as formerly in the determination of the radial velocities of stars. The study of stars having spectra of early class B has been continued, one of the purposes being to find very short-period binaries. δ Ceti and ν Eridani have been discovered to be such binaries, while $\theta^2$ Orionis was found to contain bright emission lines, which probably did not exist formerly. Also a new and detailed study has been made of the short-period binaries β Cephei, σ Scorpii, and ν Eridani. A first paper on class B stars has been published—"Spectrographic Study of Early Class B Stars"—by F. Henroteau and J. P. Henderson. About 600 spectrograms have been obtained, and a great number measured. Nova Cygni III. has been followed both spectrographically and photographically; its photographic light-curve has been published.

A bi-metallic thermostat now gives much better temperature control of the casing of the spectrograph than the former thermometer type.

A wide-angle camera has been attached to the large equatorial, with which over 100 photographs of star-fields have been obtained, embracing regions of the sky of about 20° in diameter.

*Solar Physics.*—Over 1600 observations, comprising about 14,500 strips of spectra of centre, intermediate, and limb points on the solar disc with iodine and arc comparisons, were made. Measurements of the solar rotation at 45° yielded in km. per sec. at λ5590, for three lines of average intensity 5·3—N, 1·191 and S, 1·225; and for three lines of average intensity 0·3—N, 1·141 and S, 1·213. By the method (suggested here in 1913) of measuring the change in wave-lengths of the lines in spectra of the centre of the solar disc (with reference to a fixed standard iodine absorption spectrum of vapour in a tube at 250-mm. pressure) produced by the eccentric orbital motion of the earth, a value of the solar distance was obtained from spring and autumn plates, 1916, exceeding the adopted value by two parts in a thousand. Measurements of the line-displacements in the spectra of the penumbræ of pairs of spots point strongly to inclinations of the axes of the spots which would be expected from the assumption that they are opposite ends of a vortex. There were made 105 photographs recording sun-spots with cœlostat or equatorial cameras.

*Terrestrial Magnetism.*—The magnetic survey of Canada was continued, but the work was confined almost exclusively to "repeat" stations for securing data for secular change in declination, inclination, and intensity. Forty-four stations were occupied covering the area between 83° and 57° west longitude. The eastern part was along the north shore of the St. Lawrence to the straits of Belle Isle.

*Seismology.*—At the observatory there were recorded 91 earthquakes, as against 97 in 1919 and 141 in 1918, but the number of tectonic ones, readily located from the seismograms, was consider-

ably larger than in 1919. Monthly bulletins are regularly issued and distributed over the world.

*Gravity.*—Gravity work is now being resumed after the war.

*Publications.*—During the year the observatory issued six "Publications" for distribution.

*The Dominion Astrophysical Observatory, Victoria, B.C.*
*(Director, Mr. J. S. Plaskett.)*

*The Staff.*—The staff of the observatory, consisting of the Director, Mr. W. E. Harper, Dr. R. K. Young, and Mr. H. H. Plaskett, remains the same as reported last year.

*Observing.*—The observing weather on the whole was considerably poorer than the previous year, owing mainly to the cloudy season commencing in September instead of November as usual, March, June, September, November, and December being very poor observing months. During the year 2119 star spectra were obtained on 212 nights. On 131 of these nights more than five spectra were obtained, and on 81 nights from one to five spectra were secured. On 19 additional nights, although the dome was opened and the instrument got ready, conditions were so poor that no useful observations were obtained. Practically all the observing time has been employed in photographing star spectra, with the exception of about two hours on Saturday evenings, when visitors are allowed to observe visually, and about ten hours spent on experimental and adjustment work.

*Radial Velocities.*—About 80 per cent. of the spectra obtained were in pursuance of the main radial velocity programme, the determination of velocities of about 800 Boss stars. This programme is well under way and, had it not been for the unusually poor weather during the last four months of the year, would now have been nearly completed. About 400 more spectra are required to obtain the six plates of each star, the number proposed to secure a reliable determination of the velocity. It is hoped that the observing will be completed by 1921 May, and as the measuring is practically up to date, the results should be issued some time during the coming year. In addition to the 100 spectroscopic binaries already announced, about 50 additional ones have been discovered during the course of the work. A list will be published when the observations and measures on the main programme are finished, as it will then be complete.

*Miscellaneous Investigations.*—Some further Hartmann tests of the refigured Cassegrain mirror were carried out, and a complete paper on the optical parts of the 72-inch telescope by the Director was published. The spectroscopic orbits and dimensions of the eclipsing variables U Coronæ, TX Herculis, Y Cygni, and Z Vulpeculæ have been completed by the Director. The orbits of the spectroscopic binaries H.R. 6385, Boss 5900, Boss 5070 have been obtained by Mr. Harper, who has also measured and discussed

spectra of Nova Aquilæ No. 3 and Nova Cygni No. 3. Dr. Young has completed the orbits of the spectroscopic binaries H.R. 6169, H.R. 8800, and *o* Draconis, and has also carried out and published an investigation on the stationary H and K lines of calcium in certain early-type binaries. Mr. H. H. Plaskett has published the results of an investigation of the intensity distribution in the hydrogen emission lines and the continuous spectrum of γ Cassiopeiæ by a new method of spectrophotometry, and has also completed a discussion of the intensity distribution in typical stellar spectra by the same method, which is yielding important and interesting results. Professor S. L. Boothroyd, volunteer research assistant, has completed the orbit of the spectroscopic binary Boss 4602. All these investigations are in addition, and in a sense subsidiary to, the large amount of measuring and observing entailed by the main radial velocity programme.

*Publications.*—The first twelve numbers of vol. i. of the publications of the observatory have been issued and distributed during the year, eight more numbers have been finally revised and are now being printed, while the manuscript of three further numbers has been sent to the printer.

*Helwân Observatory, Ministry of Public Works, Egypt.*
(*Director, Mr. H. Knox-Shaw.*)

*Time-Service.*—The time-service was maintained as usual. Transits were taken on 57 nights. The Riefler clock went consistently well throughout the year.

*Reynolds Reflector.*—The telescope was used on 173 nights, a greater number than in any previous year, and 250 plates were taken, the great majority of them by Mr. Gregory.

Of these 59 were on the variable nebula in Corona Australis.
153 were on other nebulæ, including 29 taken through different light filters.
16 were on comets.

In addition 17 plates were taken with the prismatic camera, three of these being on the field of the variable nebula and four on Nova Cygni.

Mr. Reynolds visited the observatory in December and made a few exposures with the telescope.

Positions of J VIII have been derived from the plates taken at the opposition of 1916, and have been published.

A discussion of the observations of the variable nebula in Corona Australis made up to 1916 has been completed.

A paper describing the nebulæ photographed from 1914 November to 1917 January is in hand.

*General.*—The usual solar radiation, meteorological, magnetic, and seismological observations were made. Bulletin No. 19 was published during the year, and No. 20 is in the press.

*Nizamiah Observatory, Hyderabad.*
*(Mr. T. P. Bhaskaran, M.A., in charge.)*

The chief work of the observatory has been, as in previous years, with the Astrographic Equatorial. The completion of the four zones $-17°$ to $-20°$ was mentioned in last year's report.

Vol. iii. (Zone $-19°$) of the *Hyderabad Astrographic Catalogue* was published, and copies were distributed during the year. Considerable progress has been made with the printing of vol. iv. ($-20°$); it is hoped that the volume will be ready for distribution shortly. The work on $-22°$ (Santiago zone) was started at the end of the year 1919, according to the suggestion of duplication made by Professor Turner (*M.N.*, 79, June), for investigating any systematic differences, in stellar images on plates taken in the northern and southern hemispheres.

171 plates with centres in Decl. $-22°$ have been obtained, out of which 149 plates containing 77,385 star images have been measured to the end of the year.

Zone $-21°$ was also included in the programme of work, and 114 plates have been secured during the year. Twenty-three of these have been measured.

The instrumental equipment remains the same as in previous years.

*Kodaikánal and Madras Observatories.*
*(Director, Mr. John Evershed.)*

The Director was absent on combined leave from May 26 to December 15, Dr. Royds being appointed Acting Director and Mr. A. A. Narayana Ayyar Assistant Director during that period.

The routine work of the observatory was continued as usual, and spectroheliograms in K light were obtained on 332 days, Hα images on 273 days, and photoheliograms on 321 days.

In a detailed study of the Hα plates Dr. Royds has brought out several new features regarding the absorption markings (*Kodaikánal Observatory, Bulletin* No. 63). In studying the prominence data for the interval 1913–1920 for periodicities, he finds that periods of 13 and $7\frac{1}{2}$ months are the principal features of the periodogram, as was the case also during the interval 1905–1912.

The grating spectrograph was employed in photographing sunlight and iron arc spectra periodically throughout the year, and in photographing Venus spectra during the first three months and in December. Spectrum photographs of sections of the sun's disc were also obtained when the conditions were favourable.

Measures of the sunlight and iron arc spectra by Mr. Narayana Ayyar indicate a rather large range of variation in the shifts of the solar lines, and his mean values for the year are in excess of those for 1919 by about 0·002 A. Measures of the Venus spectra taken early in the year when the angle Venus – Sun – Earth exceeded

90° give mean shifts about 0·005 A smaller than those measured in the control plates of direct sunlight. The December plates, so far as they have been measured, give nearly normal values, the angle at the sun being then about 70°.

By the use of Barnet Ultra Rapid plates hypersensitised with ammonia it has been possible to obtain Venus spectra with a very narrow slit, and these are the finest plates hitherto obtained. They give no evidence of any inclination of the lines due to a rotation of the planet when the terminator is placed normal to the slit.

A special ultra-violet spectrograph was erected temporarily, using a parabolic grating and a quartz collimating lens. Spectra were obtained of the east and west limbs of the sun in the region of the ammonia band at 3360, and it was demonstrated by the displacements due to the solar rotation that this band is of solar and not telluric origin.

Measures have been made of the displacements, sun − arc, of ten of the triplet bands of cyanogen near the first head at 3883. At the centre of the sun the displacement found is nearly +0·004 A, at the north polar limb +0·006 A, and at the south polar limb +0·008 A. The last value is in agreement with the shift predicted by Einstein (see *Kodaikánal Observatory, Bulletin* No. 64).

*The Solar Constant.*—During January and February, when the conditions were favourable, measures of the solar radiation were made by Dr. Royds with the Ångstrom pyrheliometer. The highest values were obtained on January 21 and 28 and February 11, and the lowest on February 4 and 17.

*Madras Observatory.*—Mr. Edward Barnes has officiated as Deputy Director. The usual observations for the time service of India have been carried out.

*Publications.*—Bulletins Nos. 62, 63, 64, and 65 and the Annual Report for 1919 were issued and distributed during the year.

*Union Observatory, Johannesburg.*
(*Union Astronomer, Mr. R. T. A. Innes.*)

There has been no change in the staff, and work has been continued on the usual lines.

During 1920 Circulars 46 to 50 were circulated, and with these circulars, in spite of the high cost of the work, were included 55 maps of the Southern Sky.

Of the maps on the scale of 1° = 36 mm., so far 66 have been printed and distributed, leaving 490 still to be done to cover the whole sky south of −19°.

Work with the Blink microscope has again been almost continuous, mainly on the proper motions of stars on the Cape plates. It is hoped to finish the examination of the Cape plates early in 1921. This examination will furnish some 4000 proper motions of stars to the 15th magnitude. Dr. Baldwin handed the

remainder of the Melbourne plates of zone – 66° to the forwarding agents for shipment to us, but the parcel has got lost—there is no evidence that it ever left the store of the forwarding agents,—and we must hope that it may yet be found. If it should not turn up within a few months, then the work done here on the other part of the zone will be published.

The Government has consented to the publication of a General Catalogue of Southern Double Stars, but printing will be delayed until the Harvard Henry Draper Catalogue of Magnitudes and Spectra is completed.

*Lovedale Observatory, South Africa.*
(*Dr. Alex. W. Roberts.*)

The work of the year has again been, mainly, the observation of southern short-period variable stars.

The observatory has now 29 years' continuous record of these stars, enabling very definite secular variation in period to be determined.

The brightness of systems of comparison stars has also been a feature of the year's work.

*Adelaide Observatory.*
(*Director, Mr. G. F. Dodwell, Government Astronomer.*)

In addition to the usual routine work, described in previous reports, the principal work undertaken during the year has been in connection with the preparatory work for fixing a point on the S.A.–W.A. Boundary (129th Meridian). Wireless time-signals from Lyons, kindly arranged by General Ferrié at the instance of Professor Cooke and Professor Sampson as a test in connection with the proposal for the general redetermination of Australian longitudes, were received at Adelaide as well as at Sydney during May, June, and July; and as the Astronomer Royal had kindly arranged for their reception at Greenwich, a preliminary determination of longitude in Australia by direct comparison with Greenwich has thus been effected. The 10 p.m. Annapolis signals were also heard faintly at Adelaide on several dates; and time-signals from Honolulu, Cavite, and Funabashi have also been received. Following on these results, it was found possible to hear Lyons with a field equipment at Adelaide, and a test was therefore arranged at Deakin, where the East-West Trans-Australian Railway crosses the border. General Ferrié again courteously arranged for the transmission of a special series of vernier signals from Lyons from November 16 to 23, and these were all satisfactorily received at the Boundary. Preliminary observations were made by an observing party acting in conjunction with Mr. Curlewis, Government Astronomer of W.A., and it is hoped to carry out a final determination if possible next April or May.

Magnetic observations were made at Ardrossan and Maitland, Yorke Peninsula, in August, and disclosed a considerable local disturbance of magnetism in that district.

Mr. J. B. O. Hosking, B.Sc., B.C.E., was appointed Chief Assistant in 1920 February.

*Melbourne Observatory.*
(*Director, Dr. J. M. Baldwin, Government Astronomer.*)

During 1920 the meridian observations have been confined to observations for local time, the commencement of a new programme being postponed until the travelling wire micrometer ordered some years ago has been received. The available staff has devoted all possible time to the work of reduction. Proper motions for the catalogue of 6089 stars for 1900 have been completed for the first 6 hours of R.A., and catalogue positions of about 2000 stars of the supplementary list of reference stars have been prepared. In September and October observations for pivot error were made, with the auxiliary telescope, which had proved insufficiently rigid during earlier observations, firmly supported. The results, although not yet completely reduced, show that the figure of the pivots is very good. A number of minor alterations have been made to the instrument in preparation for the new programme of work. Occasional observations of the meridian mark in conjunction with azimuth stars indicate that the arrangement described in the last report is quite satisfactory, and convenient in use.

In the first half of the year the work of reduction of the *Astrographic Catalogue* was being carried on by a single computer; since his transference to another State department the work has been completely at a standstill, as no one has been appointed to the vacant position.

The 8-inch equatorial has been used for observations of variable stars of long period, and 1388 observations were made during the year and forwarded to Harvard College Observatory. In addition a number of observations made some years ago and not yet published were sent for incorporation with the work of other observers.

The magnetic variation instruments at Toolangi have been in operation throughout the year. No curves have been measured, but the classification of the curves has been forwarded to De Bilt, as in previous years. Absolute values at Melbourne have been taken 22 times throughout the year, the means of the observed values being:

1920 D 8° 0′·8E H ·22874 I 67° 55′·1.

The seismograph records have been read off and the results forwarded to University Observatory, Oxford, and the verification of weights and measures, the time service, miscellaneous testing, registration of tides, etc., have been continued as in previous years.

The staff, still further diminished during the year, is quite inadequate to carry on the work of the Observatory, so that instruments are lying idle and no steps can be taken towards the reduction of the observatory records; the reduction of meridian observations can proceed only at a very slow rate, and the astrographic work is at a standstill. No funds are available either for temporary assistance or for publication.

*Sydney Observatory.*

(*Director, Professor W. E. Cooke, Government Astronomer.*)

Meridian observations of the intermediate stars between 51° and 65° south declination were completed on 1919 December 16. The observers then turned their attention to a critical inspection of the resulting positions. All anomalous figures were traced back, if necessary to the original entries, mistakes corrected, and a few observations rejected. The reductions to the catalogue are now well forward, and pivot and graduation errors have been determined. We hope to have the catalogue printed during 1921.

The astrographic work is now progressing steadily. During the year 102 catalogue plates were passed as satisfactory (up to December 14), and a start has been made with the measurements. Next year we hope to keep two star micrometers regularly employed.

In preparation for the total eclipse of 1922, a few suggested sites were visited, and a report printed and distributed.

An attempt to organise arrangements for re-determining the longitudes of Australian observatories by means of wireless time signals was made, but the Commonwealth Government, after giving considerable encouragement to the proposition, turned cold with a change of Ministry, and so the effort partially failed. With the assistance, however, of the Astronomers Royal for England and Scotland, and General Ferrié (Director of the French radio system), some very interesting trials have been made, and at the time of writing we are daily receiving, quite successfully, some special signals from Lyons, France. During the year several similar trials have been made, and on receipt of the accurate Paris or Greenwich times we hope to be able to recompute our longitude possibly within $0^{s}\cdot1$. A number of comparisons with Lyons and Honolulu ordinary daily signals indicate roughly an error in our present adopted longitude of about $0^{s}\cdot6$ or $0^{s}\cdot7$.

The usual routine duties, including University lectures, time service, seismography, reception of visitors, information for the Press and the B.A.A., etc., have been maintained as heretofore.

## Notes on some Points connected with the Recent Progress of Astronomy.

### *Observations of the Planets.*

*Mercury and Venus.*—Very little of importance has been published during the past year regarding the surface markings of these planets. An interesting series of observations of the visual magnitude of Mercury was made by W. H. Steavenson in Egypt (lat. 30° 51′ North), the planet being observed with the naked eye on forty consecutive nights from 1920 June 2 to July 11. The comparison stars used were Capella, Procyon, Pollux, and Regulus, and use was also made of the planets Jupiter and Saturn.

The resulting light curve compared with that plotted from the theoretical figures given in *N.A.* showed that the actual brightness throughout the apparition was greater than the theoretical. Steavenson suggests that the discrepancies may be due to differences of the albedo of different portions of the planet or to errors in the data upon which the calculated brightness is based.

A note, interesting to observers, is added that of 194 nights from 1920 January 1 only 15 were overcast, 168 were completely clear, and 11 partially clear (*English Mechanic*, 112, No. 2890).

*Mars.*—The apparition of 1920 was not a favourable one for observers in northern latitudes owing to the low altitude of the planet, but a good deal of observational work was carried out which has not yet been published in full, and in due course reports may be expected from observers more favourably situated.

During the previous opposition, 1917–18, although the diameter of the disc was small, much useful work was accomplished. W. H. Pickering has published at intervals in *Popular Astronomy* a series of exhaustive reports based upon observations contributed by himself and other well-known observers. These reports have been illustrated by reproductions of drawings of approximately the same longitudes by the various observers. The drawings illustrate vividly the striking differences which exist between observers, but at the same time go far to establish the reality of many of the fainter features of the planet's surface, although they may appear in various forms to different observers. Comparing these drawings, Pickering gives statistics regarding the "canals" seen by the various observers. Taking as examples the drawings of T. E. R. Phillips, L. J. Wilson, A. E. Douglass, and himself, he finds that they show about the same number of canals, and also that the canals depicted were in general the same. It is also pointed out that some canals last only for a few days, and it is thus possible for one observer to see a canal which may not be recorded by another

observing at a different time. Some conclusions are drawn regarding the duplication of canals from comparisons of drawings by L. J. Wilson and Maggini, who observed 49 canals in common. Of these 11 appeared double to Wilson and 9 to Maggini, but in only one case did the same canal appear double to both observers. Pickering gives reasons for supposing that the duplication is a subjective phenomenon (*P.A.*, 27, Nos. 2 and 3).

A brief summary of the work of the Mars section, B.A.A., during 1917–18 is given in *B.A.A. Journal*, 29, 44–52 and 220.

Following the suggestion of Antoniadi that the melting of the Polar Caps on Mars might be related to sun-spot activity, special attention was paid to the size of the N. Polar Cap during this apparition. Considerable discrepancies were found between the sizes of the Polar Cap as shown on drawings and as found from micrometer measurements. This had already been pointed out by W. H. Pickering, who considered that micrometer measures were not satisfactory for determining the real size of the cap, although they could be used to detect changes in size from night to night (*P.A.*, 28, No. 2). Following on the lines investigated by W. H. Pickering (*H.A.*, 32), T. E. R. Phillips measured a number of lunar craters by three different methods, and determined a factor by which his result should be multiplied when employing his usual method of measuring the Polar Cap by placing the two webs alongside the cap and estimating when their distance apart was equal to the major axis.

Applying this correction, the diameter of the N. Polar Cap was determined at frequent intervals from 1918 January 1 until 1918 May 21, and was found to decrease from 22°·8 in January to 7°·3 in April, after which a slow increase took place.

Probably one of the most interesting features of the planet during the 1917–18 apparition was the continued strength of the great curved streak Nepenthes-Thoth, which, following upon a great development of Lacus Moeris in 1909, was such a prominent feature of the 1911–12 and subsequent apparitions. This marking maintained its intensity almost undiminished during the 1920 opposition.

G. H. Hamilton (*Lowell Obs. Bulletin*, No. 82) has published a series of drawings of Mars made during the 1917–18 opposition. He noted that when seeing was good at times the planet was veiled, as if the atmosphere of Mars was hazy. He calls attention to the intensification of Mare Acidalium and Auroræ Sinus between the dates 1918 March 16 and April 23, and to the increase in the prominence of the canals in this region, as if due to the growth of vegetation.

Attention is also called to canals in the Maria, which became more prominent than the dark background on which they were seen. Early in March a protrusion along the N. Polar Cap was observed which later separated from the cap. This detached white area was also observed by T. E. R. Phillips and others in March and April.

G. H. Hamilton's drawings show Mars in what may be termed

the Lowellian form, the canals in general being indicated as somewhat fine lines. Summarising the results of his observations with the 24-inch telescope at the Lowell Observatory, Hamilton notes a sequence in the development of the canals and dark areas which was apparently related to the melting of the Polar Cap.

Jarry Desloges (*Astronomie*, 1920 August) reports that observations during 1920 at Setif have shown very important changes on the disc of Mars since 1918. Particular attention is called to the dark projection on the following coast-line of Syrtis Major in the position of Astaboræ Fons. This feature has been very conspicuous to most observers of Mars during the past opposition, and has been the more noticeable in that it changed the appearance of such a well-known marking as Syrtis Major.

Jarry Desloges also refers to the reappearance of the small white area Nix Olympica discovered by Schiaparelli in 1879. Measures of the position of this white spot by M. Fournier show that its position in 1920 agreed very closely with that found by Schiaparelli at the date of discovery.

W. H. Pickering also calls attention to certain changes on the surface of Mars in 1920. The canal Amenthes, for example, seems to have disappeared in 1911 and remained invisible until the present year, when it was again seen.

Changes in the latitude of the northern boundary of the Southern Maria have also been noted, which indicate that when the S. Polar Cap increases in size a portion at least of this boundary moves northward, until in one case, in longitude 193°, the border of the Mare was some 13° or 14° further north than shown on maps found to be correct at earlier apparitions.

One of the conspicuous features on Mars during the 1920 apparition was the frequent occurrence of brilliant white areas, which in many instances obscured almost entirely some of the well-known dark areas, especially when near the terminator. Thus on 1920 May 19, 20, and 22 the Syrtis Major was seen by various observers to be completely covered by a brilliant white area except at its northern end, which stood out by contrast like an intensely black marking.

A remarkable instance of the rapid disappearance of a white area in the southern hemisphere was recorded by W. F. Gale, observing under good conditions in Sydney, N.S.W., on May 5. This white area at 11 p.m. local time (10 hrs. east) covered part of Ausonia, Mare Tyrrhenum, and the southern part of Syrtis Major. By 11.14 it had disappeared.

W. H. Pickering (*P.A.*, 29, No. 1) gives details of large white areas in the northern hemisphere of the planet observed in 1920 June and July which he attributes to snow deposited during the Martian night. One of the largest of these areas, observed on June 2, covered an area of 800,000 square miles, and extended as far south as +40°, while its northern border reached to within 100 miles of the N. Polar Cap. By June 5 the southern boundary had retreated to about +60°.

Similar deposits were observed on June 11 and 18 and on July 2, 16–17; in the last two cases the white areas extended to the Polar Cap.

From observations by Lowell and himself, W. H. Pickering concludes that these "snowstorms" are to be looked for in the northern hemisphere at the time in the Martian calendar corresponding to August–September. Pickering also states that on September 7 the N. Polar Cap entirely disappeared, and it was not reobserved until 29 days later.

*Jupiter.*—A great deal of observational work has been carried out on this planet in recent years by members of the Jupiter section of the B.A.A. and others, much of which has not yet been published in full, but the results are being prepared for publication. During the apparition of 1918–19 very remarkable and extensive changes were observed in connection with such well-known features as the Red Spot Hollow and the South Tropical Disturbance. In the earlier part of the apparition these markings retained more or less the appearance of previous years, but early in 1919 the South Tropical Disturbance began to fade out, and at the end of February it was very faint, and in March it could only be seen with difficulty occasionally. When last observed its length extended over 190° of longitude.

Similarly, the Red Spot Hollow, which had been a strongly marked feature in the South Equatorial Belt for many years, began to fade out at the end of January. By March 2, T. E. R. Phillips found the preceding shoulder of the Hollow and the Red Spot itself visible, but the Hollow was very doubtful.

This disappearance of the Hollow, which has been so conspicuous a feature for many years, was accompanied by an enfeeblement of the south component of the S. Equatorial Belt along its entire length, as if some obscuring white matter had overlaid this portion of the Belt and hidden the Red Spot Hollow, together with the South Tropical Disturbance in the zone to the south of it. It is worthy of note, however, that the Red Spot itself remained visible during this period as a dusky oval which actually seemed to darken at the time when other features in its neighbourhood were apparently obscured (*B.A.A. Journal*, 29, 155–157).

One of the most remarkable occurrences on Jupiter in recent years was the outbreak during this apparition of very brilliant white spots on the Equatorial Zone which, contrary to the usual custom, appeared so bright at the *limb* as to seem to project by irradiation. Spots of this nature were recorded by Sargent (*M.N.*, 79, No. 3, 218), Ainslie, Rambaut, Phillips, and others. Phillips remarks that he had never seen such a thing previously in his long experience. Ainslie has pointed out (*B.A.A. Journal*, 29, 105) that one of these spots was large and circular although seen very obliquely, and suggests that it might be attributed to a slight elevation of a considerable part of the Equatorial Zone, and that the spot became invisible soon after leaving the limb, suggest-

ing that its visibility was due to elevation rather than to actual inherent brilliancy.

The apparition of 1919–20 (opposition 1920 February 2) was remarkable for the rapid and extensive changes which took place in the South Equatorial Belt and the South Tropical Zone. Some of these changes occurred with such rapidity that it was difficult to recognise markings after a few nights' interval. One of the most striking features of this region of the planet at the time was the appearance of several very dark spots, some of which were very small and apparently black, while others resembled satellites when seen dark during transit. Interspersed among the dark spots were brilliant round white spots giving an appearance to the Belt which was quite unlike that seen for many years. Early in the apparition the south component of the South Equatorial Belt was faint, as in the previous apparition, but later the intensity greatly increased, and the complicated structure of the Belt became remarkable. The change apparently commenced in 1920 January.

By the close of the apparition the Red Spot Hollow and the South Tropical Disturbance had reappeared (*B.A.A. Journal*, 30, 318).

Another remarkable feature of the apparitions of 1918–19 and 1919–20 was the appearance of one or two prominent dark oval markings like islands on the northern border of the North Equatorial Belt. One of these markings in particular was very prominent in 1919–20. Its colour was dark red, and on several occasions a brilliant white spot was observed in its centre.

Attention may also be called to the comparative darkness of the Equatorial Zone during 1919–20, which is maintained to the present time.

G. H. Hamilton, observing with the 24-inch telescope at the Lowell Observatory on 1919 December 5, recorded an occultation of Satellite I. by III. during which he considers that the phase of Satellite III. was visible as a dark line upon the bright disc of Satellite I. He also noted a bright polar cap on Satellite III., on which markings have been recorded at various times by other observers (*Pop. Ast.*, 28, 141).

*Saturn.*—Additional evidence regarding the transparency of the rings has been obtained through the observation of the occultation of Lal. 20654 by Saturn on 1920 March 14. This occultation was observed by Messrs. Reid, Dutton, and M'Intyre with a 6-inch Cooke photo-visual telescope at Rondebosch, South Africa. The star's magnitude is 7·3, and the seeing conditions were very good. During its passage behind the ring the star was seen both through ring A and ring B (*B.A.A. Journal*, 30, 230 and 247). This appears to be the first direct evidence that ring B is also transparent. The transparency of ring A as shown by Barnard's photographs was pointed out by P. H. Hepburn (*M.N.*, 74, 722) and confirmed by observations of the occultation of a 7th magnitude star by Ainslie and Knight on 1917 February 9 (*B.A.A. Journal*, 27, 212 and 216).

On 1920 November 7 the earth passed through the plane of Saturn's ring, the passage taking place according to the elements of H. Struve at November 7.2. The observations of numerous observers show that 12 hours before this date the ring was still conspicuous even in telescopes of moderate size, while 12 hours later it was invisible to Ainslie in the 28-inch refractor at the Royal Observatory, and also to T. E. R. Phillips, R. L. Waterfield, and H. Thomson with 18-inch and 12¼-inch reflectors (*B.A.A. Journal*, **31**, 67). That this invisibility was not due to any want of transparency in the atmosphere in England is shown by the fact that the rings were also invisible to Barnard under good conditions with the 40-inch refractor at the Yerkes Observatory (*Observatory*, **44**, 15). The dark side of the ring, although previously suspected by one or two observers, was not seen definitely in this country until November 16, when it was apparent to W. H. Steavenson with the 28-inch refractor (*B.A.A. Journal*, **36**, 116).

A useful ephemeris of the phenomena of Saturn's satellites has been prepared by L. J. Comrie and A. E. Levin, assisted by the computing section of B.A.A. (*B.A.A. Journal*, **31**, 119).

H. T.

### *Discovery of Minor Planets.*

The following list comprises the discoveries made in 1920, also (in first column) those made in earlier years by Professors Neujmin and Beljawsky at Simeis, of which the details have only recently come to hand:—

| Simeis Description. | Number. | Date. | Letter and Number. | Number. | Date. | Discoverer. | Letter and Number. | Number. | Date. | Discoverer. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1915. | | | 1920. | | | | 1920. | |
| $\Sigma r = \Sigma 1$ | 916 | Aug. 7 | GL | | Feb. 15 | B | HF | | Apr. 14 | I |
| $\Sigma w = \Sigma 4$ | 917 | Sept. 4 | GM | 925 | Jan. 13 | CS | HG | | 14 | I |
| | | | GN | 926 | Feb. 15 | R | HH | | 14 | I |
| | | 1917. | GO | 927 | 16 | W | HJ | | 14 | I |
| $\Sigma ga = \Sigma 146$ | ... | Dec. 18 | GP | 928 | 23 | R | HK | | Aug. 15 | B |
| $\Sigma gc = \Sigma 147$ | ... | 18 | GQ | | 23 | R | HL | | 20 | B |
| $\Sigma gd = \Sigma 148$ | ... | 18 | GR | 929 | Mar. 10 | R | HM | | Sept. 7 | R |
| | | | GS | 930 | 10 | B | HN | | 8 | R |
| | | 1918. | GT | | 11 | B | HO | | 12 | R |
| $\Sigma ge = \Sigma 149$ | ... | Mar. 3 | GU | 931 | 19 | G | HP | | Oct. 7 | B |
| $\Sigma gg = \Sigma 150$ | ... | 5 | GV | 932 | 23 | P | HQ | | Sept. 9 | R |
| $\Sigma gh = \Sigma 151$ | ... | 5 | GW | | Apr. 21 | R | HR | | Oct. 4 | R |
| $\Sigma gi = \Sigma 152$ | ... | 7 | GX | | 21 | W | HS | | 9 | R |
| $\Sigma gk = \Sigma 153$ | ... | 7 | GY | | May 9 | R | HT | | 10 | R |
| $\Sigma gm = \Sigma 154$ | ... | 7 | GZ | 933 | Apr. 23 | R | HV | | 10 | P |
| $\Sigma gn = \Sigma 155$ | ... | 12 | HA | | May 9 | W | HW | | 11 | R |
| $\Sigma go = \Sigma 156$ | ... | 12 | HB | | 9 | R | HX | | 12 | S |
| | | | HC | | Apr. 24 | G | HY | | Nov. 9 | R |
| | | | HD | | 14 | I | HZ | | Oct. 31 | B |
| | | | HE | | 14 | I | | | | |

The initials stand for :—

B = Dr. W. Baade, Bergedorf, Hamburg.
G = MM. F. Gonnessiat and B. Jekhowsky, Algiers.
I = Mr. R. T. A. Innes, Johannesburg.
P = Dr. J. Palisa, Vienna.
R = Herr K. Reinmuth, Königstuhl, Heidelberg.
S = Professor A. Schwassmann, Bergedorf, Hamburg.
CS = Professor J. Comas Sola, Barcelona.
W = Professor Max Wolf, Königstuhl, Heidelberg.

The following planets, unnumbered at the date of the last Report, have since received permanent numbers: Algiers D 1918 = 915, Simeis $r$ = Simeis 1 = 916 (this is not identical with Simeis 75 or with 1895 BQ, as was stated in *M.N.*, 79, 267), Simeis $w$ = Simeis 4 = 917, 1919 FR = 918, FT = 920, FV = 921, FW = 922, GB = 923, GC = 924.

The following identities have been established; the letter Σ stands for Simeis: 592 Bathsheba = 1919 FS (this had been numbered 919 before the identity was discovered); 602 Marianna = 1920 HU; 830 = Σ*gb*; 847 = 1915 XX = Σ*u*; 848 = 1915 XS = Σ*v*; 877 = Σ*ad* = Σ7; 885 = 1906 VH; 889 = Σ*gl*; 922 = 1906 VW; 924 = 1914 WE. Σ*yc* probably = 1906 WF; Σ*ye* possibly = 837.

925 has been named *Alphonsina*; this planet was of about the 9th magnitude, and was extensively observed for four months. Its orbit is given below, together with that of 1920 HZ. The latter orbit is of a cometary character, the perihelion is near the orbit of Mars, the aphelion near that of Saturn; the inclination is also very large. It shows no nebulous envelope with an exposure of half an hour, so it is difficult to apply the name *comet* to it.

| | 925. | HZ. |
|---|---|---|
| Epoch (G.M.T.) | 1920 Mar. 10·5 | 1920 Nov. 12·5 |
| M | 354° 3′ 48″·5 | 351° 45′ 27″·7 |
| $\omega$ | 198° 25′ 42″·5 | 55° 48′ 40″·6 |
| $\Omega$ | 299° 43′ 22″·3 | 21° 18′ 16″·3 |
| $i$ | 21° 7′ 40″·5 | 43° 26′ 37″·9 |
| $\phi$ | 4° 41′ 48″·7 | 40° 46′ 37″·2 |
| $\mu$ | 799″·620 | 256″·446 |
| log $a$ | 0·431415 | 0·760674 |

Both the orbits are by G. Stracke.

H. Osten has made an estimate of the total mass of the minor planets, assuming that the outstanding residuals of Mars are due to them. He deduces ⊙/4,000,000 or Earth/12. The mass could only be as large as this on the assumption that the number of small asteroids runs into millions, which seems improbable.

*Astr. Nach.*, 5078, contains tables for computing the first-order

perturbations due to Jupiter for a large number of planets, by F. Labitzke and K. Boda. These should be of great service in computing improved ephemerides. *Astr. Nach.*, 5068, 5073–74, contain tables of 505 Cava and 24 Themis, the latter by Mdlle. Julie M. Vinter Hansen.

The Trojan planets Hector and Nestor were observed by Dr. Baade in March. Planets 469 Argentina and 583 Clotilda, which had been missing for some years, were recovered in 1920. 99 Dike gave evidence of variability of light.

Marseilles Observatory has again done most useful work by circulating ephemerides and notes of observed positions.

A. C. D. C.

### *Discovery of Comets in* 1920.

Of the comets visible at the end of 1919, Finlay's was followed till March 9 by Dr. Baade at Bergedorf, being then of magnitude 18 (*Ast. Nach.*, *Circular* No. 15), and that of Metcalf-Borrelly was observed in February by Mr. Innes at Johannesburg.

Tempel's second periodic comet was detected by Mr. Kudara at Kyoto, Japan, on May $25^{d}\ 7^{h}\ 10^{m}\cdot0$, G.M.T., in R.A. $22^{h}\ 55^{m}\ 43^{s}\cdot7$, S. Decl. $4^{\circ}\ 53'\ 0''$, being then visible in a small telescope. Unfortunately, in the telegraphic announcement to Professor Bailey $22^{h}$ was transmitted as $20^{h}$, the result being the loss of two months' observations of the comet in Europe and America. It is an illustration of the importance of using the Science Observer Code, in which such a mistake is extremely unlikely, and if present is immediately detected by the control word.

The comet was independently detected by M. Schaumasse at Nice on July 19, being of magnitude 11. Mr. Van Biesbroeck observed it at Yerkes, July $20^{d}\ 19^{h}\ 54^{m}\cdot2$, G.M.T., in R.A. $1^{h}\ 53^{m}\ 24^{s}\cdot73$, S. Decl. $1^{\circ}\ 17'\ 23''$. He described it as round, of magnitude 9.

There were numerous observations after this; the latest is probably that made by Dr. Baade at Bergedorf, Nov. $17^{d}\ 11^{h}\ 12^{m}\cdot2$, G.M.T., R.A. $2^{h}\ 7^{m}\ 19^{s}\cdot46$, S. Decl. $10^{\circ}\ 43'\ 49''$. The total light was then 15th magnitude, the nucleus being 16th magnitude.

The second comet of the year was discovered on December 8 by Mr. C. J. Taylor at Cape Town. He was in bad health, and unfortunately read the hour-circle an hour wrong, which prevented the discovery from being verified till Mr. Skjellerup made it independently on December 11. The object was of magnitude $9\frac{1}{2}$, the nucleus being of magnitude 11. It was at its brightest at discovery, being then nearest both to Sun and Earth. It was moving northward fairly rapidly, and has been very extensively observed. There is as yet no decided evidence of departure from a parabola.

The following are approximate orbits of the above comets, and also of the 1918 apparition of Borrelly's Periodic Comet 1905 II. T is in G.M.T.; the equinox in each case is that of the beginning of the year of perihelion.

| Comet. Computer. | Borrelly. F. E. Seagrave. | Tempel (2). Mr. Kudara. | Taylor-Skjellerup. M. Ebell. |
|---|---|---|---|
| T | 1918 Nov. 16·8632 | 1920 June 10·196 | 1920 Dec. 11·00476 |
| $\omega$ | 352° 23′ 32″ | 186° 39′ 0″ | 340° 50′ 53″ |
| $\Omega$ | 76° 57′ 2″ | 120° 46′ 5 | 107° 46′ 26″ |
| $i$ | 30° 29′ 14″ | 12° 45′ 14″ | 22° 5′ 27″ |
| $\phi$ | 37° 57′ 11″ | 33° 54′ 21″ | |
| $\mu$ | 514″·023 | 687″·51 | |
| $\log q$ | 0·144793 | 0·12074 | 0·060159 |

The following periodic comets passed perihelion unobserved: Tempel (3)-Swift (last seen 1908) about February; Giacobini (1900 III.; last seen 1913) about May. Comets not seen since the year of discovery are not included.

There is still no news of De Vico's Comet (1846 IV.); the most probable date of perihelion is 1921 November, with an uncertainty of three years. A. C. D. C.

## *Solar Activity in* 1920.

*Sun-spots.*—The steady decline in spot activity shown since the maximum year, 1917, was maintained during 1920, for which the mean daily spot-area was about 700 millionths of the sun's visible hemisphere, or half that of 1917. The characteristics of the year were the four very large groups contrasting with several relatively small ones, and the predominant activity of the southern hemisphere. On a few occasions, especially during August, the solar disc was practically free from spots, whilst for some days in January and March the total spotted area exceeded 2500 millionths, and in September and November 1200 millionths. Of the large groups, one great disturbance is pre-eminent both for its extent and its prolonged activity. The region was situated approximately at longitude 130° and latitude −6°, and it contained the great streams of January and March. Between 1919 December 26 and 1920 January 8 a large stream of normal type was seen to form, and this appears to have been the definite commencement of activity. By the next rotation a very large complex stream had developed, 20° in length, with an area of 2000 millionths, but the group was diminishing as the west limb was approached, and when the region was again visible between February 17 and March 1 a few small spots alone remained. The following rotation brought, however, a great revival: a magnificent stream 20° in length was seen to attain its maximum development near the central meridian. A large regular spot some 9° behind the main stream, and three minor groups to the south, brought the total spotted area of the region to 3200 millionths on March 23. The large group of early September developed from a few small spots

( − 14° latitude) into a complex stream with maximum area about 1700 millionths; that of November appeared as a large stream of normal type in latitude − 10° with area 1200 millionths. Several recurrent groups were noted during the year, notably the above-mentioned ones, and also a large regular spot in latitude $+13\frac{1}{2}°$ seen during June and July. A "great" magnetic disturbance appeared associated with the March group. H. W. N.

*The Prominences.*—The mean daily areas in square minutes of arc, derived from the Kodaikánal photographic records, are as follows:—

| | North. | South. | Total. |
|---|---|---|---|
| 1920 January to June . . . | 1·99 | 2·34 | 4·33 |
| July to December . . . | 2·10 | 2·17 | 4·27 |

These figures show a slight increase over those of the previous year. The mean numbers increase from 13·2 for the first half year to 15·9 for the second.

The general distribution in latitude has remained essentially the same as in 1919, notwithstanding some fluctuations in the different zones of activity, and between the northern and southern hemispheres. No large prominences have been observed in the polar regions above latitude 60°.

Metallic prominences were fairly numerous in the sun-spot zones, and displacements of the hydrogen lines were also frequent. The displacements towards red again slightly exceed those towards violet at the limb, and on the disc near spots 75 per cent. of the whole number (161) were towards red.

Prominences photographed on the disc as absorption markings show an increase in area of 38 per cent. compared with 1919; their distribution in latitude was identical with that of the limb prominences.

A striking change has occurred in the distribution between east and west. In previous years up to 1919 there has always been an excess of absorption markings in the eastern hemisphere of the sun, but in 1919 this excess was negligibly small, and in 1920 there is a marked excess west of the meridian, the areas of those on the east side being only 47·5 per cent. of the whole. About the same western preponderance is shown also by the prominences at the limb, and the western prominences were also about 14 per cent. brighter than those on the east limb.

A great eruptive prominence was photographed on December 31 on the west limb. It bore a striking resemblance to the prominence of 1919 May 29, and occupied the same region of latitude, extending from + 5° to − 42° as an immense arch. Between $8^h$ and $10^h$ I.S.T. the prominence reared up to a great height and rapidly faded, the highest parts ascending to 16′ above the limb.

J. E.

*Solar Research in* 1920.

*Solar Periodicity.*—Meissner (*Ast. Nach.*, 211, 261) has carried out a fresh analysis of sun-spot frequency figures and arrives at periods $9^{y}\cdot9$, $11^{y}\cdot9$, $14^{y}\cdot5$ as probably real. Danjo (*C.R.*, 171, 1127) has made an attempt to trace the solar periodicity back through much earlier times by correlating solar activity with the intensity of lunar eclipses.

*Sun-spots.*—The magnetic polarity of the great sun-spot group of 1920 March 21 is analysed by S. B. Nicholson (*Ast. Soc. Pac.*, 32, 244). The changes of magnetic polarity are traced as the group developed from a normal small tripolar spot into a remarkable stream dying out as a single spot. Cortie (*M.N.*, 80, 574) discusses the same spot and its relation to terrestrial magnetic phenomena. He and H. W. Newton (*Jour. B.A.A.*, 30, 192) trace the changes of appearance of this spot group at successive appearances. Newton (*M.N.*, 80, 463) carries out the same piece of work for the sun-spot and facular area connected with the eclipse prominence of 1919. The north end of the prominence and not the main stem is connected with the disturbed area.

Hale and Ellerman announce (*Ast. Soc. Pac.*, 32, 272) that the new Mount Wilson photographic map of the sun-spot spectrum from 3900 A. to 6600 A. is completed, and is to be placed on sale at cost price. The scale will be 1 cm. per Angstrom. All kinds of magnetic polarisation phenomena are shown, and variations of intensity of certain sun-spot lines. Special work is being done on lines of anomalous magnetic behaviour in sun-spot regions.

*Solar Atmosphere.*—M. N. Saha has published (*Phil. Mag.*, 40, 472, 809) two very suggestive papers on ionisation in the solar atmosphere. He explains the presence of spark lines in the chromosphere as due to the variation of the ionisation potentials of elements with the vapour density. He uses Nernst's theorem relating to reaction-isobars in explanation of the presence or absence of the lines of individual elements at different levels of the sun's atmosphere. In particular he points out that only for stars of very high temperature can we hope to see the ionised helium line at $\lambda4686$.

T. Royds (*Kodaikánal Obs. Bull.*, 63) discusses the dark H$\alpha$ markings on the sun. He shows that they are inclined to the solar meridian at angles which increase with the latitude by amounts which require something more than the known varying rotation to account for them. By a study of the bright margins to these markings, and of the absorption seen at the base of the corresponding prominence when the prominence is on the limb, he shows that the cooler outlying hydrogen gases of the prominences lie in the chromosphere, while the dark markings extend above it by about 10″ of arc. Cortie (*Obs.*, 43, 387) compares the solar faculæ drawn at Stonyhurst with the calcium flocculi shown

in spectroheliograms. He finds striking agreements, and places the faculæ at the bases of the higher-level flocculi. E. W. Maunder (*M.N.*, **80**, 724) discusses the distribution of solar faculæ. Faculous activity follows that of the spot frequency. A persistent difference is shown between the east and west limb, the former having 3 per cent. more prominences than the latter.

C. Gouy (*C.R.*, **170**, 638) examines the possibility of large-scale convection currents in the sun, and finds that they are not precluded by the growth of viscosity with temperature and pressure. Duffield (*M.N.*, **80**, 262), in a discussion of various causes which could shift slightly lines in the solar spectrum, offers alternative schemes for circulation in the atmosphere which would fit in with the observed data and would imply the acceptance or rejection of the displacement involved in the equivalence hypothesis of Einstein. Eddington (*M.N.*, **80**, 823) examines the density of an atmosphere sustained by radiation pressure. He points out that at most a weight of 2 dynes per sq. cm. could be supported, and that a comet's tail or the corona, if supported in this manner, must have an average density of the order of $10^{-15}$. F. E. Fournier (*C.R.*, **171**, 501, 560) suggests an explanation of the displacement of the star images in the eclipse photographs in terms of an atmosphere round the sun of varying oscillatory density. This atmosphere is not regarded as being in equilibrium, but as consisting largely of matter being driven out from the sun. Fournier suggests that the motion of the perihelion of Mercury, the tails of comets, and the outbursts of novæ can be explained in terms of this eruptive solar atmosphere.

*Displacement of Spectrum Lines.*—J. Evershed (*Kodaikánal Obs. Bull.*, **64**, and *Obs.*, **43**, 153) examines the strong triplet bands in the cyanogen band at λ3883 in the solar spectrum. Rejecting St. John's fainter lines as not corresponding in intensity in the solar and laboratory spectra, or as being too difficult to measure, he confirms the Einstein effect for the north and south limb, and suggests an outward radial motion of the absorbing gases to account for the difference at the centre of the disc. C. E. St. John (*Obs.*, **43**, 158) emphasises the need of using only clearly separated single lines. For such lines in the cyanogen bands and for certain magnesium lines measured by Adams and himself he finds no evidence of shift. St. John also criticises severely (*Obs.*, **43**, 260) Grebe and Bachem's evidence for the Einstein shift. A. Perot (*C.R.*, **171**, 229) examined the wave-lengths of lines in the solar cyanogen band at λ4197. He gets a high value for the faculæ and a low one for the filaments—agreeing with the motions found by Deslandres. Correcting for the motion, he gets the Einstein shift almost exactly. A criticism has been made by J. W. Nicholson and T. R. Merton (*Proc. R.S.*, **98**, A, 261) of ultra-refined measures of unsymmetrical lines, and this may have an application to much of the work done on these very small shifts.

*Solar Spectrum.*—W. F. Meggers (*Allegheny Obs. Publ.*, **6**, 13) publishes details of an extension of the solar and atmospheric

absorption spectrum from 6500 A. to 9000 A. The new table overlaps Rowland's tables by 800 A. The predominance of terrestrial absorption over solar absorption in this region is very striking—60 per cent. of the lines are terrestrial. Iron is most strongly represented in the solar spectrum, and the presence of potassium, europium, and free oxygen are confirmed. K. Burns (*Lick Obs. Bull.*, **10**, 64) reports that a study of the region 9000–9900 A. shows no certain lines of solar origin of intensity greater than 0 on Rowland's scale. All the stronger lines measured were of terrestrial origin.

*Magnetic Field.*—F. E. Seares (*Obs.*, **43**, 310) gives a detailed account of the work at Mount Wilson on the general magnetic field of the sun—the relation of field strength to level, the location of the magnetic axis, and the strength of the field. The account is supplemented by a useful bibliography.

*Eclipse Results.*—T. A. Miller (*Ast. Soc. Pac.*, **32**, 207) deduces from a study of plates taken from different stations during the eclipse of 1918 June 8 that some very prominent coronal arches moved outwards during the eclipse at about 16 km./sec. Unsymmetrical curvature of the polar rays away from the general axis of coronal symmetry is also noted by him.

C. G. Abbot and A. F. Moore publish (*Ap. J.*, **51**, 1) a photograph of the corona secured by them at the eclipse of 1919 May 29. They draw attention to the many narrow streamers extending outwards — two solar diameters in nearly every direction.

*Solar Radiation.*—C. G. Abbot gives an account (*Nat. Acad. Sci.*, **6**, 4) of a new method of determining the solar constant of radiation which is not so dependent as previous methods on a perfect sky. It consists of measuring the sky brightness by a new instrument (the pyranometer), also the quantity of humidity from the spectrum-energy curve, and determining the atmospheric transparency as a function of these two data.

*Miscellaneous.*—Prosperi discusses (*Mem. Soc. Ast. Ital.*, **1**, 66) the solar diameter from measures over the period 1874–1900. He deduces the mean value 961″·14 for the semi-diameter.

C. G. Abbot has written (*Nat. Acad. Sci.*, **6**, 82) the second research survey of the National Research Council of the United States. The two points that are chiefly emphasised for future work are the needs for further solar research stations in cloudless climates for the study of variations in solar radiation, together with further statistical inquiries into the relations of solar and terrestrial phenomena. F. J. M. S.

### *The Application of Interference Methods to Astronomy.*

The possibility of applying interference methods with advantage to the problem of measuring the angular diameters of stars was first indicated by Fizeau in a Report on the Bordin Prize of the

Académie des Sciences. In view of recent developments, it is of interest to recall the passage :—

"Il existe, pour la plupart des phénomènes d'interférence, tels que les franges d'Young, celles des miroirs de Fresnel, et celles qui donnent lieu à la scintillation d'après Arago, une relation remarquable et nécessaire entre la dimension des franges et celles de la source lumineuse ; en sorte que les franges, d'une ténuité extrême, ne peuvent prendre naissance que lorsque la source lumineuse n'a plus que des dimensions angulaires presque insensible ; d'où pour le dire en passant, il est peut-être permis d'espérer qu'en s'appuyant sur ce principe et en formant, par exemple, au moyen de deux larges fentes très-écartées, des franges d'interférence au foyer des grands instruments destinés à observer les étoiles, il deviendra possible d'obtenir quelques données nouvelles sur les diamètres angulaires de ces astres" (*C.R.*, **66**, 934, 1868).

Stéphan was the first to test the possibilities of the method. He found, from elementary considerations, that if a star has an appreciable diameter the interference fringes produced by placing two slits over the object-glass would completely disappear for a certain distance apart of the slits given by $\alpha = \lambda/l$, $l$ being the distance, $\lambda$ the mean wave-length, and $\alpha$ the angular diameter of the star (*C.R.*, **76**, 1008, 1873). He further showed that, instead of narrow slits, extended apertures could be used provided that the two apertures were equal and possessed two axes of symmetry and that their width was small compared with their distance apart. In this way much more light could be obtained, making the fringes more easily visible. Using the 80-cm. Foucault refractor of the Marseilles Observatory, Stéphan examined Sirius and other stars. The results are given in a paper entitled "Sur l'extrême petitesse du diamètre apparent des étoiles fixes" (*C.R.*, **78**, 1008, 1874). The least diameter measurable was $0''{\cdot}16$, and, although the fringes did not disappear, Stéphan was able to conclude from their appearance that "les expériences citées ne prouvent pas seulement que le diamètre apparent des étoiles examinées est inférieur à $0''{\cdot}16$, elles montrent encore que ce diamètre est une très faible fraction du nombre précédent."

The theoretical possibilities of the method were more fully explored by Michelson in a paper entitled "On the Application of Interference Methods to Astronomical Measurements" (*Phil. Mag.*, fifth series, **30**, 1, 1890). The following results were obtained :—

(i) If the object is a circular disc of uniform brightness and of apparent angular diameter $\alpha$, then the fringes will vanish for the distances apart of the slits given by

$$l = (1{\cdot}22,\ 2{\cdot}24,\ 3{\cdot}26,\ \ldots)\lambda/\alpha.$$

(ii) If the illumination is not uniform but falls off towards the limit, as in the case of the sun, the corresponding distances become

$$l = (1{\cdot}33,\ 2{\cdot}38,\ \ldots)\lambda/\alpha.$$

(iii) If a double source is observed, whose distance apart is

large compared with the separate diameters, the fringes vanish for distances of the slits given by

$$l = (\tfrac{1}{2},\ \tfrac{3}{2},\ \tfrac{5}{2},\ \ldots)\lambda/\alpha,$$

$\alpha$ being the angular separation of the two components, provided that the length of the slits is perpendicular to the line joining the centres of the two sources.

The theory of the first of these cases, the uniformly bright circular disc, has been discussed in greater detail by Hamy (*Bull. Astron.*, **10**, 488, 1893; **16**, 257, 1899; *C.R.*, **127**, 851, 1898), the results agreeing with those obtained by Michelson. The method is well adapted for the measurement of the angular diameters of small bodies, being accurate and not so dependent upon good definition as micrometrical methods. The loss of light arising from the use of narrow slits is serious, however. At the Paris Observatory, using narrow slits, it was not found possible with the equatorial coudé to measure the diameters of Jupiter's satellites, owing to the difficulty of observing the fringes. Hamy therefore extended the theory to the case in which the slits are of a width which is comparable with their distance apart. If they are equal and rectangular, of width $a$ and distance between their centres $l$, the formula $\alpha = 1{\cdot}22\lambda/l$ obtained by Michelson must be replaced by

$$\alpha = 1{\cdot}22\frac{\lambda}{l}\left\{1 + 0{\cdot}765\left(\frac{a}{l}\right)^2\right\}.$$

The method has been applied both by Hamy and Michelson to the measurement of the angular diameters of the larger satellites of Jupiter. Hamy used the large Equatorial Coudé of the Paris Observatory, and prepared screens for placing over the objective in which the apertures were of such dimensions that $a = \frac{1}{3}l$, and the diameters $a$, calculated by the above formula, decreased by $0''{\cdot}1$ with successive screens. The screens for which the fringes became least distinct were found, and by interpolation the angular diameters of the satellites were estimated to $0''{\cdot}01$ (*C.R.*, **128**, 583, 1899; *Bull. Astr.*, **16**, 271, 1899). Michelson, observing with the 12-inch equatorial at Mount Hamilton, used adjustable narrow slits (*Pub. Ast. Soc. Pacific*, **3**, 274, 1891). The angular diameters of the satellites obtained in this way, reduced to a distance of five units for Jupiter, were as follows:—

| | I. | II. | III. | IV. |
|---|---|---|---|---|
| Hamy . . | $0''{\cdot}98$ | $0''{\cdot}87$ | $1''{\cdot}28$ | $1''{\cdot}31$ |
| Michelson . | $1''{\cdot}02$ | $0''{\cdot}94$ | $1''{\cdot}37$ | $1''{\cdot}31$ |

The agreement between the two series is very satisfactory.

In spite of the advantages which the interferometer method possesses for the measurement of small angular diameters or separations, the method does not appear to have been further employed until the past year, when, at Michelson's suggestion, it was tried again with the 100-inch telescope.

When applied to the measurement of the angular separation of close double stars the interferometer method more than doubles the theoretical resolving power of the telescope. In the case of ordinary methods of observation the least angular separation which the telescope can resolve is given by $1{\cdot}22\lambda/a$, $a$ being the aperture of the telescope. In the interferometer method the least angular separation which will cause the fringes to vanish is $\frac{1}{2}\lambda/l$, so that the smallest angle which can be thus measured is $\frac{1}{2}\lambda/a$. The resolving power is therefore increased in the ratio 2·44 : 1 ; in the case of the 100-inch telescope from ″·05 to ″·02.

As a suitable object for testing the method, Capella was chosen. It was known to be a spectroscopic binary, but visual methods had failed to separate the components, although an angular separation of 0″·06 would have given a perceptible elongation. The telescope was used as a Cassegrain combination with a focal length of 1600 inches. The slits, 1 inch in length and $\frac{1}{8}$ inch wide, were placed 47 inches from the focus, where the cone of light had a section of 2·9 inches. When the first observation was made with the telescope set on Capella, it was found that the fringes disappeared in position-angle 148° or 328° when the slits were separated by 1·55 inches. This corresponds to a separation of the components of 0″·042, and the vanishing of the fringes indicates further that the two components are of approximately equal brightness : had they been of unequal brightness, the fringes would have merely showed minima and maxima of contrast. For Altair, the fringes remained unaltered for all position-angles of the slits.

The possibilities of the method are indicated by the following results for Capella, given by Hale (*Nature*, 106, 268, 1920) :—

| | Position-Angle. | Distance. |
|---|---|---|
| | ° | ″ |
| 1919 December 30 . . | 148·0 | 0·0418 |
| 1920 February 13 . . | 5·0 | ·0458 |
| „ 14 . . | 1·0 | ·0451 |
| „ 15 . . | 356·4 | ·0443 |
| March 15 . . | 242·0 | ·0505 |

The plotted points fall accurately on an ellipse and provide an accurate determination of the orbit. The method possesses other advantages which should appeal to double-star observers : it is not necessary to have very good definition, the fringes remaining visible when the seeing is 2 on a scale of 10 ; also the accuracy of observation, both for distance and position-angle, is the same whatever the separation of the components.

In his original paper in the *Phil. Mag.*, Michelson indicated the possibility of employing the method in conjunction with an interferometer, thereby enabling the available aperture to be very considerably increased. This extension of the method has recently been tested with success at Mount Wilson : a steel girder 20 feet in length is fixed across the upper end of the tube of the 100-inch

telescope and two adjustable mirrors, inclined at 45° to the girder and to the telescope axis, reflect light from a star towards two other mirrors near the centre of the girder and thence down the telescope tube. The available aperture of the telescope is thereby increased to 20 feet, which is sufficient to enable the angular diameter of stars exceeding 0″·02 to be measured. The manipulation of an interferometer of such size requires a high degree of experimental skill, and it is stated that after shifting the mirrors from one-half to one hour is required to find the fringes. The girder is capable of rotation so as to test whether the fringes vanish in all position-angles, thus excluding the possibility of the vanishing being due to a double source. The giant red stars of low density provide the most favourable objects for measurement, and a definite result has already been obtained in the case of Betelgeuse, for which an angular diameter of 0″·045 has been obtained. This may be compared with a theoretical value of 0″·042 derived by Wilsing from a determination of the effective temperature, on the assumption that the star radiates as a black body. Other stars which would appear favourable for examination are $\alpha$ Scorpii, $\alpha$ Boötis, $\alpha$ Tauri, $\gamma$ Crucis, and $\beta$ Gruis. Further developments of the method will probably occur in the near future. Meanwhile, it is interesting to note that the recent measurement is in accordance with Stéphan's conclusion—made fifty years ago, at a time when there was little theoretical information as to the order of magnitude of the angular diameters of stars—that the diameters must be considerably smaller than 0″·16.

H. S. J.

### *Double Stars.*

*New Pairs and Measures.*—During the year 1920 the particulars of 93 new double stars of less than 5″ separation were published.

W. S. Franks (*M.N.*, **80**, 215) gives the measures of 248 miscellaneous pairs made with the 6⅛-inch Cooke refractor of the Brockhurst Observatory, 1918–19. The separation of all pairs except one is over 5″, and of most over 10″.

Dr. J. E. de Vos van Steenwijk (*M.N.*, **80**, 223) gives the measures of about 250 double and proper motion stars. The observations were made with the 10½-inch refractor of the Leyden Observatory. Although most of the pairs are wide—up to 5′—some well-known double stars are included.

T. E. Espin (*M.N.*, **80**, 329) publishes the 14th series of double stars observed by himself and Mr. Milburn with the 24-inch Calver reflector. The measures refer to 45 old pairs and 80 new pairs Es 1769–1805 and Milburn 107–149. These new lists contain respectively 26 and 30 pairs under 5″ separation. All the stars are faint, and include a number not in the B.D. They are situated in a zone of Declination +54° to +61°.

T. E. R. Phillips (*M.N.*, **80**, 643) has measured 49 well-known

Σ and 0Σ pairs with an 8-inch refractor at Headley. Special attention was again given to ξ Boötis and 70 Ophiuchi.

A. Hall and E. C. Bower (*A.J.*, No. 763) give measures of 70 Ophiuchi and faint stars in the neighbourhood.

R. Jonckheere (*A.J.*, No. 765) publishes the measures of 17 new double stars under 5″ separation, J 1331–1347, discovered at Lille in 1914.

H. C. Lord (*A.J.*, No. 768) gives the measures of 17 double stars—mostly Σ stars—made with the 12½-inch refractor of the Emerson McMillin Observatory in 1919.

C. P. Olivier (*A.J.*, No. 772) has measured 100 pairs, many from recent lists of Aitken and Jonckheere. The separation of all pairs, except Sirius, is under 5″. The observations were made with the 26-inch refractor of the Leander McCormick Observatory. He also gives 20 new pairs, all under 5″, of which Ol 66–77 were found on parallax plates and Ol 78–85 were found at the telescope. These pairs are faint. The same writer, in collaboration with S. A. Mitchell, gives photographic measures of Krueger 60 for the years 1916–19 from plates for parallax determination. Olivier has in the press * the measures of 95 double stars, including 32 new pairs under 5″ made from parallax plates. The separation for most pairs is under 5″.

C. Luplau Janssen (*A.N.*, **210**, 225) gives the measures of 33 double stars made by himself and G. Haarth at the Urania Observatory, Copenhagen. These are mostly fairly wide Struve pairs.

E. Bernewitz and F. Pevel (*A.N.*, **211**, 13) give observations of ν Geminorum as a visual double star. This star was known to be a spectroscopic binary with the comparatively long period of 9·6 years, and the observations were made near the computed time of maximum separation. The observations were made on five nights by each of the observers with the 65-cm. refractor of the Berlin-Babelsberg Observatory. The measured separation was 0″·15.

W. Doberck (*A.N.*, **211**, 321) publishes the observations of about 240 double stars observed at Sutton in the years 1914–19. Important pairs were observed on a large number of nights—these include Castor, ζ Cancri, ξ Ursæ Majoris, Σ 1785, ξ Boötis, η Coronæ, ξ Scorpii, λ Ophiuchi, ζ Herculis, 70 Ophiuchi, ζ Aquarii.

During the year 1920 three extended series of double-star observations have been issued in observatory publications. These are the visual observations made at Leiden by J. Voûte in the years 1910–13, and at Brussels by G. van Biesbroeck in the years 1913–15 and the photographic observations made at Potsdam by E. Hertzsprung, 1914·0–1919·4.

Voûte's observations are published in *Annals of the Leiden Observatory*, **10**, pt. 2. There are in all 1755 observations of 370 pairs made with the 10½-inch refractor of the Leiden Observatory. Most of the pairs were known to be in relative motion, and therefore many interesting systems are included. There are 263

* *Publications of Leander McCormick Observatory*, **3**, 679.

Σ stars and 64 OΣ stars in the list. The results are given in considerable detail. The observer's head was held so that the line joining his eyes was either parallel to or perpendicular to the line joining the components, and for each observation the position is stated. Observations were made with and without a reversion prism. The question of probable errors is discussed by the internal agreement of the observations made on different nights and by different methods of observing, and also by means of formulæ derived from all known observations. For the latter work 118 systems were treated by least squares so as to give the position-angles and distances as linear functions of the time. These results might be utilised for the determination of hypothetical parallaxes.

In *Annals of the Royal Observatory of Belgium*, **14**, pt. 3, are given the fourth series and last of double-star observations made by van Biesbroeck before he left Uccle to carry on his work at the Yerkes Observatory. These measures form a continuation of previously published observations, and were made with the 38-cm. refractor. There are 164 pairs, most of which are fairly well known and many are close.

*Photographic Observations of Double Stars.*—In most branches of astronomical observation demanding the highest precision visual work has gradually been replaced by photographic. This has resulted largely from increased sensitiveness of the photographic plate and from advances in the construction of long-focus telescopes and of the mechanism required for their accurate driving. One of the great advantages of the photographic method over the visual is that a permanent record is secured, and this may be measured and remeasured at different times and in different conditions. With visual observations unknown errors due to personality in the observer are introduced at the source, and it is difficult or impossible to eliminate them afterwards. In double-star astronomy, where we have to deal with small relative displacement of close stars through long intervals of time, photography, if possible, would be of the greatest value. For close double stars of unequal brightness the personality of observers may amount to 10° or more. This is particularly the case with the OΣ stars, where it is often difficult to utilise the observations of the discoverer, although they were made with the most powerful instrument of the epoch. The fact that photography gives a permanent record leads to the hope that by it double stars might be accurately compared through long intervals of time, free from the personal peculiarities of different observers. Up till quite recently there has been little hope that photography would assist in the measurement of pairs of stars sufficiently close to show orbital motion in a reasonable time. The success which has attended parallax determinations by photography has led to new efforts in attempting the photography of double stars. In the last Report of the Council attention was drawn to photographic measures by E. Hertzsprung of ξ Ursæ Majoris, which confirmed the existence of a dark body perturbing that system. These measures were only examples of systematic

work which Hertzsprung has carried out at Potsdam, and the complete observations made in the interval 1914·0 to 1919·4 are given in the second part of vol. xxiv. of the *Publications of the Potsdam Astrophysical Observatory*.

For this work the instrument used was a 50-cm. *visual* refractor. The plates employed were sensitive to yellow and green light—mean wave-length about 5450 A. The mean scale value was 1 mm. = 16″·39, corresponding to a focal length of 12·58 metres.

When ordinary photographic plates are used the effect of atmospheric dispersion at 45° zenith distance is to displace K stars 0″·18 relative to A stars. Precautions must therefore be taken so as to ensure that approximately the same effective wave-length is used for all stars. The following short table shows the success attained :—

| Without Filter. | | With Filter. | |
|---|---|---|---|
| Mean Type. | Mean Effective Wave-length. | Mean Type. | Mean Effective Wave-length. |
| A 1 | 5421 A ± 10 A | B 9 | 5520 A ± 6 A |
| F 8 | 5418 A ± 14 A | F 8 | 5533 A ± 6 A |
| K 2 | 5463 A ± 8 A | K 0 | 5538 A ± 9 A |

A difference in wave-length of 42 A produces a difference in the refraction at 45° zenith distance of 0″·014. As this is of the same order as the accidental errors, it was not applied as a correction to the measures.

In stellar photography errors are introduced in the relative positions of stars of unequal brightness if the images are not perfectly symmetrical. To avoid these errors a grating was placed over the objective so as to make the first diffracted images of the principal star approximately equal to the central image of the fainter star. The gratings used had an interval between the central image and the first diffracted image of approximately 1, 2, 3, and 4 magnitudes. It was thus possible to have the images equal to within half a magnitude. The distance between the diffracted images gave the effective wave-length.

Another point to which attention was paid was the effect of two near photographic images on each other. On account of local exhaustion of the developer the images are apt to appear too far apart at the commencement of the development, but later they draw together. It was found that for close pairs with bad definition the measured distances were too small. It was suggested that in future different exposures made on the same plate might be arranged thus, ● · ● · ● · , so that equal and opposite effects might lead to no displacement of the inner images.

From the photographic measurement of double stars it is hoped to detect with certainty comparatively small relative motion and to find pairs in which the Keplerian motion is disturbed by dark bodies. We may note here that Hertzsprung's measures of

$\xi$ Ursæ Majoris completely support Nörlund's result that there is a perturbation with a period of 1·8 years.

There are in all measures of 16,680 exposures on 408 plates of 126 double stars. The actual measures are given in detail, and the results are collected in a catalogue. As a specimen we give the results for 70 Ophiuchi and $\xi$ Boötis:—

70 *Ophiuchi* (mags. 4·28, 5·98):

| | | |
|---|---|---|
| 1915·195 | 140°·93 ± 0°·07 | 4″·554 ± 0″·005 |
| 1917·150 | 137·78 ± 0·07 | 4·977 ± 0·006 |
| 1919·376 | 134·56 ± 0·06 | 5·389 ± 0·006 |

$\xi$ *Boötis* (mags. 4·80, 6·82):

| | | |
|---|---|---|
| 1914·300 | 110·12 ± 0·38 | (2·084) ± 0·014 |
| 1918·116 | 80·29 ± 0·24 | 2·290 ± 0·009 |
| 1919·385 | 71·83 ± 0·15 | 2·384 ± 0·006 |

These results appear to indicate a new order of accuracy in double-star work. As mentioned above, C. P. Olivier has in press the measures of 95 double stars mostly with separation less than 5″ made on parallax plates. We may therefore look forward to the time when the wider pairs will be all observed photographically, although stars under 1″ separation will require visual observation.

*Double Stars showing Relative Motion.*—During the year 1920 the orbits of a considerable number of double stars have been computed. For some, especially those of short period, orbits have been computed for the first time. The following table gives in successive columns the number in Burnham's General Catalogue, the common double-star name, the period in years, the semi-major axis, the eccentricity, the place of publication, and the initials of the author.

| *β*.G.C. | Name. | Period. | *a*. | *e*. | Publication. | Computer. |
|---|---|---|---|---|---|---|
| 482 | Σ 73 | 124·2 | 0″·97 | 0·71 | *M.N.*, 80, 545 | J.J. |
| 1144 | Σ 228 | 167·4 | 0·97 | 0·31 | ,, 80, 546 | ,, |
| 1761 | Σ 412 | 216·9 | 0·41 | 0·54 | ,, 80, 547 | ,, |
| ,, | ,, | 270· | 0·49 | 0·56 | *Publ.A.S.P.*, 32, 216 | R.G.A. |
| 2093 | OΣ 77 | 95·0 | 0·44 | 0·05 | *M.N.*, 80, 548 | J.J. |
| 2187 | β 1185 | 28·9 | 0·23 | 0·19 | *Publ.A.S.P.*, 32, 218 | R.G.A. |
| 2383 | β 552 | 88·2 | 0·63 | 0·52 | *M.N.*, 80, 548 | J.J. |
| ,, | ,, | 86· | 0·56 | 0·51 | *Publ.A.S.P.*, 32, 217 | R.G.A. |
| 4355 | OΣ 185 | 59·6 | 0·35 | 0·61 | *M.N.*, 80, 586 | J.J. |
| 5223 | OΣ 208 | 110·1 | 0·32 | 0·47 | ,, 80, 549 | ,, |
| 6158 | Σ 1639 | 361· | 1·00 | 0·93 | ,, 80, 550 | ,, |
| 6566 | Σ 1768 | 220·4 | 1·20 | 0·86 | ,, 80, 551 | ,, |

| β.G.C. | Name. | Period. | $a$. | $e$. | Publication. | Computer. |
|---|---|---|---|---|---|---|
| | | | ″ | | | |
| 6641 | Σ 1785 | 193·6 | 2·55 | 0·46 | *M.N.*, 80, 552 | J.J. |
| 6999 | Σ 1879 | 177·9 | 0·79 | 0·62 | ,, 80, 552 | ,, |
| 7001 | OΣ 285 | 88·5 | 0·33 | 0·55 | ,, 80, 553 | ,, |
| 7259 | Σ 1938 | 234·8 | 1·27 | 0·56 | ,, 80, 554 | ,, |
| 7642 | Σ 2052 | 153·2 | 1·62 | 0·92 | ,, 80, 741 | ,, |
| 7649 | Σ 2055 | 110·3 | 1·33 | 0·86 | ,, 80, 555 | ,, |
| 7748 | Δ 15 | 126·1 | 0·94 | 0·44 | ,, 80, 556 | ,, |
| 7783 | Σ 2107 | 154·5 | 0·78 | 0·39 | ,, 80, 557 | ,, |
| 7936 | OΣ 327 | 88· | 0·26 | 0·8 | ,, 80, 743 | ,, |
| 8353 | OΣ 341 | 19·8 | 0·30 | 0·96 | *Publ. A.S.P.*, 32, 220 | R.G.A. |
| 9319 | Σ 2525 | 354·9 | 1·12 | 0·93 | *M.N.*, 80, 558 | J.J. |
| 9605 | Σ 2579 | 321·0 | 2·12 | 0·19 | ,, 80, 558 | ,, |
| 9650 | OΣ 387 | 128·0 | 0·57 | 0·18 | ,, 80, 559 | ,, |
| 10559 | Σ 2729 | 151·7 | 0·70 | 0·38 | ,, 80, 560 | ,, |
| 12290 | β 80 | 85·7 | 0·79 | 0·77 | ,, 80, 561 | ,, |
| 12696 | Hn 60 | 40·8 | 0·50 | 0·35 | ,, 80, 786 | ,, |
| ... | $p$ Eridani | 218·9 | 8·02 | 0·72 | *A.J.*, No. 762 | B.H.D. |
| ... | γ Centauri | 203·4 | 1·92 | 0·30 | ,, No. 765 | ,, |

R.G.A. = Professor Aitken, B.H.D. = Mr. Dawson, J.J. = Mr. Jackson. Mr. Jackson gives an ephemeris to 1935 or later for his orbits.

G. C. Comstock (*A.J.*, 764) has discussed the motion of the bright components AB of 70 Ophiuchi relative to three faint neighbouring stars *a*, *b*, *c*. He found the ratio of the masses B : A = 0·79, and the sum of the masses 2·04. Proper motions are deduced for the faint stars.

The system Krueger 60 has received considerable attention. We have already mentioned photometric measures by Mitchell and Olivier. The system has been discussed by F. Pavel and E. Bernewitz (*A.N.*, 211, 121). Using a parallax of 0″·252, they find the masses of the components of the close pair to be 0·260 and 0·216 times that of the sun.

Professor Aitken, in the re-examination of pairs discovered by himself, gives (*Pub. A.S.P.*, 32, 56) a fifth list of pairs for which considerable motion has taken place since their discovery.

*Miscellaneous Results.*—Professor L. Becker (*M.N.*, 80, 598) deals with the capture hypothesis of binary stars. He analyses the directions of the major axes of well-determined orbits and finds them symmetrical about a point in R.A. 110° with a small positive declination. This result is to be compared with the vertex of preferential motion about R.A. 94°, Dec. +12°. The agreement supports the theory that in the course of time the binary systems of one star stream pass near stars of the other stream, so that there is an interchange of one star of each system and a new binary

combination is produced. A peculiar distribution of the directions of the major axes, not required by the capture theory, is also brought out.

C. Wirtz and W. Schreyer (*Astr. Nach.*, **210**, 297) discuss Dembowski's observations of the colours of double stars. The original description is reduced to a numerical scale, and from all pairs for which the principal component was not fainter than 7·0 magnitude a catalogue is formed. There are 1114 double stars for which 5170 estimations of colour were made. The relationship between the spectral type and the scale is determined, and the colour determinations are compared with those of Osthoff's Catalogue. It is found, in confirmation of previous results, that the difference in colour of the components increases with the difference in magnitude. The observations made with the 7-inch and 5-inch telescopes are treated separately, and the results obtained prove that Dembowski's estimations were very reliable for such limited optical power.

In *Harvard Circular*, 221, Miss Cannon gives a list of 116 stars of composite spectra—*i.e.* stars showing a spectrum produced by the superposition of two spectra of different types. This list brings the total of such objects discovered by her to 261. Of the stars in the new list 43 have previously been announced as visual double stars while 73 have not. For some of the known visual doubles the companion is too faint to give a spectrum, so these results prove that the principal star is double. As most of the stars are bright it is improbable that many of the 73 will be found to be visual double stars, although one or two have recently been discovered to be double by Aitken. On the other hand, they are not ordinary spectroscopic binaries which are discovered not from composite spectra but from variable radial velocity. Those which give a variable radial velocity will be important, as it will be possible to determine their relative masses. J. J.

## *Stellar Spectroscopy in* 1920.

*Nebulæ.*—The publication of the new Lick volume on nebulæ (*Lick Obs. Publ.*, **13**) is the outstanding event of the year. Two papers in this volume call for reference here: W. W. Campbell and J. H. Moore have investigated the differential motions of the bright-line nebulæ. A very complicated structure for individual spectral lines corresponding to different portions of the nebulæ has been revealed—particularly a doubling across the central portion and twists at the principal condensations. Rotation and expansion are indicated, but are insufficient in themselves to explain all the observed data. High average radial velocities have been deduced for the nebulæ, and, under certain simple assumptions, values for the nuclear masses, large compared with the sun, have been deduced from the rotation. W. H. Wright, in the same volume, discusses the wave-lengths for the nebular lines. He tabulates all the known

lines, distinguishing between those strong in the nucleus and those strong in the nebular envelope. He confirms the close relation of the nuclei with Wolf-Rayet and certain B-type stars; the presence of nitrogen and carbon is confirmed. Attention is drawn to the striking extension of the continuous spectrum of the nuclei towards the ultra-violet, the corrected maximum of radiation lying beyond the accessible range of spectrum. Prismatic slitless spectra show well the different behaviour of different lines. Wright suggests a classification of nebulæ into three classes depending on the presence or absence of the lines at 4686A and 3889A in the spectrum. W. H. Wright gives (*Ast. Soc. Pac.*, **32**, 65) the wave-lengths of four new nebular lines in the red at 7009, 7065, 7138, 7325. E. P. Hubble (*Ast. Soc. Pac.*, **32**, 154) finds for the faint sprawling nebulosity of *N.G.C.* 1499 a strong continuous spectrum extending beyond the head of the Balmer series. Otherwise the spectrum has the usual hydrogen, helium, and nebular lines.

*Novæ. Nova Aquilæ III.*, 1918.—J. Lunt (*M.N.*, **80**, 519) deals with the spectrum of the nova after the earliest observations. He notes the identifications of the two chief sets of displaced lines. A careful study of the complex 4640 band gives elements at 4604, 4634 (N), 4641 (N), 4650 (C), and 4686 (He). The first line is of unknown origin. The presence of bright nitrogen is clearly shown. F. E. Baxandall (*M.N.*, **81**, 66) has shown the presence of nitrogen and oxygen absorptions in the spectrum from 1918 June 14 to June 21. He shows that with the same velocity displacement the much-discussed pair of dark lines about λλ4054 and 4060 are to be identified with the nitrogen lines at λλ4097, 4103. The velocities involved reach nearly 3000 km./sec. Harper (*Pub. of Dominion Obs., Ottawa*, **4**, 259) gives a useful journal of changes noted each day. He notes differences in the velocities given by the hydrogen and metallic absorptions—a bright band at 4972 and absorption lines in the hydrogen bands displaced only about 7A to the violet. Miss A. J. Cannon (*Harvard Annals*, **81**, 31) gives an account of the Harvard plates 1918 June 9–1919 September 26. A special feature is made of the oscillatory stage when both spectrum and brightness were fluctuating. In a later paper (*M.N.*, **80**, 696) Lunt discusses the spectrum in 1919. He notices the persistence of the absorption corresponding to a velocity of −450 km./sec., and accepts velocity as the explanation of the uniform structure of the bands. Cortie (*M.N.*, **80**, 205) gives details of the visual spectrum in 1919 July and August, while Norlind (*Ast. Nach.*, **211**, 87) gives similar details for 1920 August.

J. H. Moore gives (*Ast. Soc. Pac.*, **32**, 232) further details of the changing structure of the complex bright bands. They are widening outwards at right angles to the spectrum at a rate of 1″·8 a year for the nebular bands and at about half that rate for the hydrogen bands. The central maxima are diminishing in relative intensity. Moore comments on the symmetrical placing of the maxima at the red and violet ends. In a second note (*Observatory*,

43, 283) he explains the difficulties in the way of accepting radial expansion as the explanation of the broadening of the bands. F. G. Pease (*Ast. Soc. Pac.*, 32, 334) reports the discovery of a bright bar across the disc of Nova Aquilæ, an S-shaped line twisted about the N.-S. axis being found in the slitless spectrograms.

*Nova Cygni III.*, 1920.—The most complete statement of the spectral changes in this nova so far available is the account from August 22 to October 27 given by W. J. S. Lockyer and D. L. Edwards (*M.N.*, 81, 38). The usual displaced $\alpha$ Cygni absorption spectrum was accompanied by a similar bright-band spectrum, first seen August 23. The bright bands developed two maxima. The bands at λ4640 and λ5007 were first seen on September 6 and October 22 respectively. A comparison of the light curve and the velocity curve given by the absorptions is not confirmed from other sources. The hydrogen absorption lines widen to the violet, and Orbinski's method fails to give accurate results. W. H. Wright (*Ast. Soc. Pac.*, 32, 273) mentions the fine undisplaced H, K, $D_1$ and $D_2$ lines—the displacement being as usual equivalent to that of the solar motion. He notes the extraordinary strength of Hα and the multiple nature of the hydrogen absorption lines—six components with $-10^4\delta\lambda/\lambda$ having values 26·5, 30·0, 35·9, 44, 51·8, 59·7. The metals agree with the lowest displacement factor. W. S. Adams and A. H. Joy (*Ast. Soc. Pac.*, 32, 276) note that while the displacements increase for hydrogen, those for the metals remain nearly constant after August 25. The displacement is a minimum at maximum brightness for the star. Carrasco (*Annuario de l'Obs. de Madrid*, 1921) studies the first spectral phase over the range λλ3360–5080. His plates show the great brightness of the star in the extreme ultra-violet. The Solar Physics Observatory, Cambridge, sends a preliminary note (*M.N.*, 81, 50) discussing the four components of the hydrogen absorptions on September 11 for which $-10^4\delta\lambda/\lambda$ was 27, 40, 45·7, 59·3, and gives a number of enhanced metallic lines for which the corresponding factor was 24·6. Cortie (*M.N.*, 81, 57) claims that oxygen is present in the bright-band spectrum of September 11, 19. W. H. Wright (*Ast. Soc. Pac.*, 32, 340) mentions that the two dark lines to the violet of Hδ so prominent in Nova Aquilæ have been found on plates between September 14 and 29 with values for $-10^4\delta\lambda/\lambda$ ranging from 80 to 90. This, though greater than for other lines so far identified in the nova, does not reach the value found for the displacement of these lines in Nova Aquilæ. D'Azambuja (*C.R.*, 171, 466) notices the strong continuous extension into the extreme ultra-violet. Other observations, mostly visual, of the spectrum of this nova are given in *Ast. Nach.*, 211, 385, 401, 418, and 449; 212, 77: also in the *Journal B.A.A.*, 31, 23.

*Nova Geminorum II.*, 1912.—F. J. M. Stratton gives (*Annals Solar Physics Obs., Cambridge*, 4, 1, and Abstract, *M.N.*, 80, 540) a complete account of the published observations of this nova, together with a full discussion of a very complete series of plates secured at Cambridge and Allegheny. He supports the general

explanation of the phenomena in terms of Doppler effects. P. Brill (*Ast. Nach.*, 211, 29) discusses the behaviour of the two bands 3483, 3431 during the autumn of 1912. The former is strong when the star brightens and at the same time the other band weakens.

*Nova Lyræ*, 1919.—W. S. Adams and A. H. Joy (*Ast. Soc. Pac.*, 32, 154) describe the spectrum as bright bands, mostly suggestive of hydrogen, nebulium, nitrogen, and oxygen, with displaced nitrogen and oxygen absorption lines. W. H. Wright (*ibid.*, 167) confirms the nitrogen bands.

*Nova Ophiuchi IV.*, 1919.—W. S. Adams and C. Burwell (*Ap. J.*, 51, 121) give details of a spectrum of the familiar early type six weeks after passage through maximum.

H. Thomson (*Journal B.A.A.*, 30, 252) gives an account of visual observations made on a number of recent novæ.

*Special Studies.*—R. K. Young (*Journal R.A.S. Canada*, 14, 389) discusses the problem of the so-called fixed calcium lines in the early type stars. He connects the phenomenon with an outer layer of the star's atmosphere which may or may not share in the stellar rotation, but which shares in the stellar motion. A relationship between great mass and these lines is indicated, and a useful list of references given for the 37 stars concerned. H. Ludendorff (*Ast. Nach.*, 212, 3) ascribes the phenomenon to a cloud which did not originally belong to the star, but one through which the star is moving. Ludendorff links up the B stars with the nebulæ through the massive stars which have large velocities.

F. Henroteau and J. P. Henderson (*Dom. Obs. Ottawa*, 5, 1) discuss the rôle of gaseous clouds in connection with early type stars, with special reference to the widths of the lines. There are indications that the widths of the lines in early B class spectra depend on the depths or densities of nebulous clouds. The presence of well-defined emission lines central in the broad hydrogen absorption lines is noted. W. Carl Rufus (*Journal R.A.S. Canada*, 14, 139) notes that the calcium envelope extends beyond the range of the hydrogen envelope. Further references are *Journal R.A.S. Canada*, 14, 409, and *Publ. Astroph. Obs. Victoria*, 1, 105.

A study of the part of radiation pressure in stellar physics, by F. Henroteau (*R.A.S. Canada*, 14, 93), suggests that Cepheids may be explained by a combination of orbital motion due to gravitation with motion due to light pressure.

Amongst other investigations should be noted:—

The spectra of the Hyades and of the Præsepe cluster, by Kohlschütter (*Ast. Nach.*, 211, 289). This is a catalogue of stellar spectra viewed in connection with colour-index. The radial velocities of the two clusters confirm Schwarzschild's view of their common motions.

Temporary shifts in the absorption lines of $\gamma$ Argus (*Ap. J.*, 52, 39). C. D. Perrine notices absorption lines to the violet of the bright helium bands; the lines are displaced by an amount

proportional to the wave-length, indicating a velocity of −1380 km./sec.

The spectrum of T Tauri. R. F. Sanford notices (*Ast. Soc. Pac.*, 32, 59) the presence of bright lines of hydrogen and enhanced (spark) metals. Accompanying are strong absorption lines which are Class III. furnace lines. The magnitude of the star was 10, and the velocities for the two types of lines were equal.

The spectrum of the companion to Castor and of W.B. $16^h{\cdot}906$. This is a binary star described by W. S. Adams and A. H. Joy (*Ast. Soc. Pac.*, 32, 158) as having two components, both dwarfs, of type K8, but with bright hydrogen and H and K lines.

Ten stars of Class B, with bright H$\alpha$, catalogued by P. W. Merrill and M. C. Humason (*Ast. Soc. Pac.*, 32, 336).

The spectrum of $\eta$ and $\gamma$ Argus. W. M. Worssell (*Union Obs. Circular*, 46) gives a list of lines on the red side of H$\beta$, mostly enhanced iron, for $\eta$ Argus, and a corresponding list for $\gamma$ Argus, mostly carbon.

*Classification.*—C. D. Shane (*Lick Obs. Bull.*, 10, 79) describes the spectra of certain Class N stars carrying previous work further towards the red. Titanium and vanadium are the most prominent elements, but scandium and yttrium are newly identified. Bright lines are not identified, but their reality urged. Bands of the Swan spectrum and of cyanogen are identified. For variable stars of this class it is noticed that the bright hydrogen lines vanish at minimum and that then the dark D lines are exceptionally wide. The carbon absorption diminishes at maximum; the wave-length of maximum radiation moves towards the red at minimum. In general the veil theory is supported.

Miss Cannon continues, in *Harvard Annals*, 93, 94, the Henry Draper Catalogue of stellar spectra down to $12^h\ 0^m$. Miss Cannon catalogues (*Harvard C.O. Circular*, 221) 116 fresh stars of composite spectra, of which 73 were not previously known to be binaries, and 18 stars of varying spectra.

*Variables.*—J. S. Plaskett (*Journal R.A.S. Canada*, 14, 409) gives a table of the absolute dimensions of all eclipsing variables so far worked out, noticing particularly the increase of mass with progression to early type. In particular this paper deals with the eclipsing variables U Coronæ, TX Herculis, and Y Cygni. In the case of Y Cygni it is noticed that the H and K lines are stationary, and have a velocity different from that of the centre of mass of the system by 49 km./sec.

J. S. Plaskett (*Publ. Dominion Astrophysical Obs. Victoria*, 1, 132) discusses the eclipsing variables U Ophiuchi, RS Vulpeculæ, and TW Draconis. He notes that the spectroscopic phase is later than the photometric phase, but in the opposite direction to that found by Schlesinger. In a further note on U Coronæ (*ibid.*, 1, 187) he notices that out of four variables two have the larger star the fainter of the pair.

W. S. Adams and A. H. Joy discuss (*Ast. Soc. Pac.*, **32**, 163) the spectrum of *o* Ceti at minimum. The bands and low temperature lines become relatively more prominent. A number of narrow bright lines develop which they identify with low temperature iron lines. As minimum approaches the bright hydrogen lines broaden and are displaced to the red, while broad bright helium lines develop. Narrow bright metallic lines project beyond the continuous spectrum and beyond the hydrogen and helium lines. Absorption lines appear to the violet of H$\beta$ and H$\gamma$. C. D. Shane (*ibid.*, 234) identifies provisionally bands of yttrium of some form in *o* Ceti. He finds H$\alpha$ to H$\rho$ bright. H$\delta$ is always the brightest, while H$\epsilon$ is always faint and occasionally absent. H$\alpha$ and H$\kappa$ show anomalous displacements towards the red.

P. W. Merrill (*Ast. Soc. Pac.*, **32**, 247) examines the spectrum of R Aquarii at minimum. He finds that the bright nebular lines are invariable in absolute intensity during the variation of the star.

Spectrum of T Pyxidis. Miss Cannon (*Harvard C.O. Bull.*, **716**, 7) notes the presence of bright hydrogen bands flanked by absorption lines on the violet side as in novæ.

M. L. Humason (*Ast. Soc. Pac.*, **32**, 200) notices the extreme brightness of H$\alpha$ in T Pyxidis, while in the ultra-violet the dark components of the hydrogen lines are strengthened relatively to the bright components.

Spectrum of U Cygni. Miss Cannon (*Harvard C.O. Bull.*, **705**) notices this star of Class N as having bright hydrogen lines.

*Radial Velocities.*—A valuable catalogue of radial velocities for over 2000 stars, compiled from the library of the Cape Observatory, is given by T. Voûte (*Natuurk Tidschrift von Ned.-Indie*, Deel 80, tweede aflevering). The Harvard spectra, and where available the parallaxes, are given for the stars.

W. E. Harper gives (*Publ. Ottawa Obs.*, **4**, 289, 309, 331) the radial velocities of 37 stars, including 3 new binaries.

R. E. Wilson (*Lick Obs. Publ.*, **13**, 187) gives for the mean velocity of 17 nebulæ in the Magellanic Cloud the value +276 km./sec. E. Hertzsprung (*M.N.*, **80**, 782) suggests that the differences found between the separate nebulæ are consistent with a common parallel motion.

A. Hnatek (*Ap. J.*, **41**, 198, and *Ast. Nach.*, **210**, 245 and 327) gives lists of radial velocities for stars determined at Vienna.

R. F. Sanford (*Ast. Soc. Pac.*, **32**, 278) gives two stars of Class R with the large velocities of −416 km./sec.

R. K. Young (*Publ. Astroph. Obs. Victoria*, **1**, 105) gives the velocity of 12 Lacertæ. The orbit curve varies in shape and amplitude, and the *fixed* calcium lines H and K share to some extent in the fluctuations.

W. Carl Rufus (*Ap. J.*, **41**, 252) gives 5 stars of spectrum Oe 5 with variable radial velocities, and notices that most stars of this class have variable velocities, while the H and K lines show a much smaller range of variation.

*Spectroscopic Binaries.*—The following orbits have been determined:—

| Star. | Author. | Reference. | Period. | Eccentricity. |
|---|---|---|---|---|
| | | | d | |
| Boss 5026 | Harper | *Victoria, B.C.*, **1**, 157 | 7·635 | 0·55 |
| ι Delphini | ,, | ,, **1**, 153 | 10·996 | 0·20 |
| Boss 4507 | ,, | ,, **1**, 125 | 2·824 | 0·017 |
| ι Geminorum | Young | ,, **1**, 119 | 9·590 | 0·21 |
| Boss 4669 | ,, | ,, **1**, 131 | 9·612 | 0·47 |
| HR 8427 | ,, | ,, **1**, 193 | 2·172 | 0·0 |
| Boss 2285 | Joy and Abetti | *Ap. J.*, **50**, 391 | 14·296 | 0·28 |
| S Sagittæ | Hellerich | *A.N.*, **210**, 65 | 8·382 | 0·54 |
| SU Cygni | ,, | ,, | 3·846 | 0·31 |
| Boss 4602 | Boothroyd | *A.S.P.*, **32**, 329 | 10·527 | 0·30 |
| η Boötis | Bianchi | *Mem. Soc. Ast. Ital.*, **1**, 31 | 495 | 0·23 |
| ν Geminorum | Harper | *Ottawa*, **4**, 279 | 9ᵛ·6 | 0·20 |

J. S. Plaskett, W. E. Harper, R. K. Young, and H. H. Plaskett give (*Publ. of Astroph. Obs. Victoria*, **1**, 10) a list of 100 binaries discovered out of 574 stars examined. A preponderance of stars of types B, A, F is noted. Only 2 stars are of type A–M. One B star in 3 appears to be a binary.

*Laboratory Results.*—A. Fowler (*M.N.*, **80**, 692) gives a new list of enhanced lines of nitrogen between Hβ and Hε. Important from the stellar point of view are λλ4634·3, 4640·8 found in novæ and nebulæ.

Hemsalech (*Phil. Mag.*, **39**, 241) analyses the electric furnace lines into those of thermo-electric origin as distinct from lines of purely thermal origin. A. S. King (*Ap. J.*, **52**, 187) answers Hemsalech, maintaining for many of his lines a variation solely dependent on temperature so long as the potential drop employed is kept very small. The same writer (*ibid.*, **51**, 13) describes mixed absorption and emission spectra of metallic vapours produced in the electric furnace. High-temperature lines were shown in emission and low-temperature lines in absorption.

Compton and Lilly (*Ap. J.*, **52**, 1) describe the effect of a trace of neon on the spectrum of helium. The lines at 5331, 5341 were brought out very strong.

P. W. Merrill (*Ap. J.*, **51**, 236) gives a list of 58 lines, mostly nitrogen, oxygen, or argon, in spark spectra in the range 5927–8719Å.

*Instruments.*—J. S. Plaskett describes in detail (*Publ. Dom. Astroph. Obs. Victoria*, **1**, 81) the spectrograph attached to the 72-inch telescope.

*Stellar Radiation.*—J. Wilsing gives (*Potsdam Astroph. Obs.*, 24, 1) a theoretical study of stellar colours and luminosities, with an application of Planck's radiation equation to the absolute size of a star.

B. Lindblad (*Uppsala Univ. Årsskrift*, 1920, 1) gives an elaborate theoretical discussion of the distribution of intensity in the continuous spectra of the stars, with special relation to luminosity and spectral type. Starting with Schwarzschild's and Schuster's treatment of the problem of radiative equilibrium and scattering in a foggy atmosphere, he applies data given by the relative distribution of intensity in different regions of the sun's disc and in different portions of the spectrum to determine the temperature of the solar envelope, for which he finds the value 6720°. He extends his work to cover the relative behaviour of the outer atmosphere of giant and dwarf stars in so far as selective absorption in the ultra-violet is concerned, and so far as relations can be determined between luminosity and effective wave-lengths.

H. H. Plaskett applies (*M.N.*, **80**, 771) the wedge method of Merton and Nicholson to a determination of the intensities of the continuous spectrum and of the bright lines of $\gamma$ Cassiopeiæ. He finds the maximum intensity at 4300A, and deduces an effective temperature of 6800°, lower than that usually assigned to B stars. A secondary maximum at 4600A suggests that Wien's and Planck's laws do not hold. Variations of intensity of the bright hydrogen lines are noted.

K. Lundmark and B. Lindblad discuss (*Ap. J.*, **50**, 376) the photographic effective wave-lengths of nebulæ and clusters. The effective wave-length of planetary nebulæ agree with that of stars of type A8, that of the spirals with stars of type G2.

C. Nordmann (*C.R.*, **171**, 392) discusses the divergence from the black body radiation of a number of stars. He finds that stars of G and lower type give out too much heat in comparison to light owing to the absorbing action of their outer atmospheres. The same writer (*ibid.*, 492) applies his heterochrome photometer to Nova Cygni III. He deduces a rise in temperature between August 27 and August 29, but his results are invalidated by the overpowering effect of the bright hydrogen bands. The same criticism applies to the value of the colour-index for Nova Aquilæ III. given by P. Guthnick and P. Hügeler (*Ast. Nach.*, **210**, 345).

*Miscellaneous.*—H. Deslandres (*C.R.*, **171**, 451) discusses the detection in stellar spectra of different layers by the isolation of such bright lines as K2. Changes such as are found in the K2 radiation in the sun are being looked for in the stars at Meudon.

V. M. Slipher (*Observatory*, **43**, 391) criticises the method suggested by L. Rodés for obtaining the diurnal rotation of planets.

C. E. St. John and S. B. Nicholson (*Ast. Soc. Pac.*, **32**, 332) give $8''{\cdot}813 \pm 0''{\cdot}017$ as a determination of the solar parallax obtained from certain spectroscopic observations of Venus.

F. J. M. S.

*The Astrographic Chart and Catalogue.*

A few additions have been made to the published results of this work since the report last made in 1918 February. The table below gives the complete list of the publications now available in a form designed to show the areas of the sky covered.

| Limits of Declination. | Limits of Right Ascension. | Observatory. | Contents. | Charts. Plate Centres. | Charts. Number published (approx.). |
|---|---|---|---|---|---|
| | h h | | | Greenwich. | |
| 90° to 64° N. | 0 to 24 | Greenwich | Vols. i., ii., Measured co-ordinates, diameters | 90°–65°. | Zone complete. |
| | | | Vol. iii., Equatorial co-ordinates, magnitudes | Rome. | |
| 65 to 59 | 0 to 24 | Rome | Measured co-ordinates, diameters | 55° N. ... | 75 |
| | | | | Brussels. | |
| 55 to 48 | 0 to 3 | Catania | Measured co-ordinates, equatorial co-ordinates, magnitudes | 37° N. ... | 10 |
| | | | | 35 ,, ... | 20 |
| | | | | 33 ,, ... | 50 |
| 47 to 39 | 3 to 12 | Helsingfors | Measured co-ordinates, equatorial co-ordinates, magnitudes. | Paris. | |
| | | | | 24° N. ... | 180 |
| 40 to 33 | 90 plates | Potsdam | Measured co-ordinates, magnitudes | 22 ,, ... | 170 |
| | | | | 20 ,, ... | 90 |
| 34 to 31 | 250 plates | ,, | ,, ,, ,, | 18 ,, ... | 80 |
| | | | | Bordeaux. | |
| 32 to 24 | 0 to 24 | Oxford | Measured co-ordinates, diameters | 16° N. ... | 150 |
| | | | | 14 ,, ... | 110 |
| 25 to 20 | 0 to 24 | Paris | Measured co-ordinates, magnitudes | 12 ,, ... | 40 |
| | | | | Toulouse. | |
| 18 to 13 | 0 to 24 | Bordeaux | ,, ,, ,, | 9° N. ... | 120 |
| | | | | 7 ,, ... | 100 |
| 12 to 10 | 0 to 6 | Toulouse | ,, ,, ,, | 5 ,, ... | 100 |
| | | | | Algiers. | |
| 10 to 4 | 0 to 24 | ,, | ,, ,, ,, | 3° N. ... | 160 |
| | | | | 1 ,, ... | 160 |
| 1 N. to 3 S. | 0 to 24 | Algiers | Measured co-ordinates, magnitudes | 1° S. ... | 180 |
| | | | | San Fernando. | |
| 14 to 16 | 0 to 6 | Tacubaya | Measured co-ordinates, equatorial co-ordinates, diameters | 3° S. .. | 20 |
| | | | | 5 ,, ... | 70 |
| | | | | 7 ,, ... | 180 |
| 16 to 20 | 0 to 24 | Hyderabad | Measured co-ordinates, diameters | 9 ,, ... | 180 |
| | | | | Tacubaya. | |
| 31 to 38 | 0 to 24 | Perth (W. A.) | Measured co-ordinates, magnitudes | 11° S. ... | 70 |
| | | | | 13 ,, ... | 90 |
| 40 to 44 | 0 to 24 | Cape of Good Hope | Standard co-ordinates, diameters | 15 ,, ... | 110 |
| | | | | 16 ,, ... | 90 |

The figures in the first column which give the limiting declinations show in some cases the overlap of adjacent zones, in others the regions of declination that are still to be supplied.

The observatories that will fill these gaps are shown by the following statement of allotted zones, indicated by the declinations of the plate-centres :—

| | | | |
|---|---|---|---|
| Rome | 64°–55° N. | Hyderabad | 17°–20° S. |
| Catania | 54–47 ,, | Santiago de Chile | 21–23 ,, |
| Paris | 24–18 ,, | Cordoba | 24–31 ,, |
| Bordeaux | 17–12 ,, | Perth (W. Aust.) | 32–40 ,, |
| Toulouse | 11–5 ,, | Cape of Good Hope | 41–51 ,, |
| Algiers | 4 N.–2 S. | Sydney | 52–64 ,, |
| San Fernando | 3 S.–9 ,, | Melbourne | 65–90 S. |
| Tacubaya | 10–16 ,, | | |

Different methods and order of publication are followed by the individual observatories. In general each plate is measured and published as a separate unit, and the stars are shown in duplicate or triplicate because of the overlapping of the plates. Volume iii. of the Greenwich series is a catalogue of the brighter stars, being those that have already appeared in some meridian catalogue, which are arranged in zones of declination, those in each in order of right ascension. The Helsingfors Observatory proposes ultimately to collect the star places and publish a similar catalogue. The catalogues of Rome and Hyderabad are similar to that of Oxford, and give measures of co-ordinates and diameters of the stars with constants to convert these into standard co-ordinates and magnitudes. Each volume comprises a zone of declination from R.A. $0^h$ to $24^h$; but Catania, Helsingfors, and Tacubaya, on the other hand, are issuing volumes or parts, each of which covers a limited section of right ascension and not the complete zone. These three observatories give not only the measured co-ordinates but also the standard co-ordinates computed from these and the derived equatorial co-ordinates. The Potsdam volumes already published contain a selection of plates which follow no precise order, the complete list being given in the last published volume. The total number of plates in the region allotted to Potsdam is 1232, and the number of these of which the measures are already published is shown in the table, but it is scarcely possible to specify the exact limits of R.A. they cover. Paris, Bordeaux, and Algiers publish a complete zone in each volume, and those already issued cover consecutive zones, so the places of the stars are in the main in duplicate. The Toulouse publications include only portions of zones, and at present only the zones of odd declination have appeared.

An approximate number of the charts already distributed is shown zone by zone. The number of charts required to fill zone 55° is 120; zone 37°, 144; zones 35° and 33°, 160 each. For all the other zones shown the total number is 180, and from this the progress of the publication may be inferred. H. P. H.

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## ADDRESS

*Delivered by the President, Professor A. Fowler, on the award of the Gold Medal to Professor Henry Norris Russell.*

The Gold Medal of the Society is this year awarded to Professor Henry Norris Russell for his "Contributions to the Study of Stellar Evolution." It is my duty and privilege, as your President, to present some account of the work which has led the Council to make this award. Professor Russell has fortunately found it possible to undertake the journey from America in order to be with us to-day, and I feel sure that we shall all be united in giving him a cordial welcome.

It would be difficult to find a more comprehensive expression of all that is now implied in the term "stellar evolution" than one recently given by our Medallist himself. What he rightly regards as the central problem of stellar astronomy he has formulated as follows: "From the existing data, and from all further data which may be secured by methods new or old, to deduce a theory of stellar evolution; that is, of the changes in the temperature, density, brightness, spectrum, and other observable characteristics of a star with the progress of time, and of the dependence of these changes upon those factors which are invariant for a given system, such as mass, angular momentum, and chemical composition. Such a theory must satisfactorily represent the observed properties of the general run of the stars and the relative abundance of the different types, and must be capable of extension so as to account for the exceptions to the usual rules."

The views as to stellar evolution which were most widely prevalent when our Medallist entered this field of scientific inquiry may be summarised in a very few words. The hypothesis of the generation of stars from nebulæ, which took more definite form through the observations of our first President, Sir William Herschel, and rather more than half a century later seemed to have been placed upon an unassailable foundation by the memorable observation of the spectrum of a nebula by Sir William Huggins, may be said to have been universally accepted. It was also generally agreed that the various classes of stellar spectra which had been revealed by the work of Secchi and others were not to be interpreted as indicating varying chemical composition from star to star, but as being mainly due to differences of temperature of the absorbing gases in the stellar atmospheres. Thus, all stars being assumed of essentially the same composition, the order of development was believed to be from nebulæ to the helium stars, thence to the other class of white stars typified by Sirius, through

the yellow or solar stars, to red stars, which were apparently on the verge of extinction as luminous bodies.

This sequence is most conveniently expressed in the well-known classification adopted by Professor Pickering and his associates at the Harvard College Observatory. It begins with the gaseous nebulæ, designated Class P, passes to the bright-line, or Wolf-Rayet, stars of Class O, and from these to dark-line stars of Class B, of which lines of helium are especially characteristic. The next main division, Class A, comprises the white stars in which hydrogen absorption lines are the predominant feature. Then follows Class F, forming a transition stage between Class A and Class G, the latter of which includes yellow stars of solar type. Next in order comes Class K, including the yellowish-red stars, with a modified spectrum of solar type; and finally the red stars of Class M, which are characterised by broad bands due to titanium oxide. More than 99 per cent. of the many thousands of stars which have been spectroscopically studied by the Harvard observers fall into one or other of the six great groups B, A, F, G, K, M, of which Class B includes the hottest and whitest and Class M the coolest and reddest stars. The few outstanding stars, apart from those of Class O at the head of the series, fall in Classes N and R, which from their redness and spectra would seem to come near the end of the Harvard series. The typical spectra, it should be remarked, are not abruptly divided one from another, but are connected by the well-marked transition stages represented by the decimal system introduced at Harvard, in which, for example, G5 indicates a spectrum half-way from Class G to Class K. The continuity and simplicity of the spectral sequence furnishes strong evidence that the differences in spectra cannot be due to variations of chemical composition, for in that case an almost infinite variety of spectra would be expected.

Investigations of the velocities of stars and nebulæ suggested later that the planetary nebulæ might have no place in this general evolutionary scheme. As Campbell viewed the matter, it was considered probable that the majority of the stars had been formed directly by the condensation of irregular nebulæ, and that the planetaries, in company with the Wolf-Rayet stars, which have closely related spectra, should be regarded as belonging to a different order of phenomena in intimate association with novæ. With this qualification, the evolutionary sequence from nebulæ, through the white to the yellow and red stars, may be said to have been accepted by nearly all but Sir Norman Lockyer.

While agreeing that nebulæ were representative of the first luminous stages of stellar history, Lockyer regarded these bodies as meteoritic swarms at a comparatively low temperature, and in place of associating them with the hottest stars, he considered that the first stages of condensation were represented by the relatively cool red stars of Class M. Recognising that further condensation of such a swarm of meteorites would be accompanied by a rise in temperature, Lockyer classified the stars in an ascend-

ing and a descending temperature series, with the hottest stars near the middle. Lockyer produced much valuable experimental evidence in support of the general temperature sequence, and by using the enhanced lines of the various elements as a means of identifying stars of equal temperature, he pointed to differences in the spectra of some of the stars at the same level of temperature as justifying the ascending and descending branches of his "temperature curve." Lockyer's sequence, however, was not very favourably received by astronomers. In particular, the grounds on which he placed the M stars in immediate relation to the nebulæ failed to carry conviction, and the peculiarities which led him to place certain stars on the ascending side of the temperature curve were perhaps not regarded as of a sufficiently fundamental character to justify so great a distinction.

The probability of the existence of stars of rising temperature was also recognised by Sir William Huggins. Relative density, as indicative of relative potential energy, according to Huggins, should be the guiding principle of a natural system of stellar classification. The evidence then available suggested that the B stars were the most diffuse, and should accordingly come first in the order of evolution. Having regard to Lane's law, it followed that the highest stellar temperature would come later. Thus, while in agreement with the general sequence now conveniently expressed by the Harvard classification, Huggins was led to suppose that the maximum temperature was probably reached in the solar or G stars. The observational evidence adduced in support of this view, however, has proved to be illusory.

From the nature of the problem, as so well defined by our Medallist, it will be evident that the study of stellar evolution calls for the co-ordination of observational data obtained among many different lines of astronomical research. No single investigator could hope to obtain for himself more than a small fraction of the observations which a theory of evolution should embrace, and he might even be successful in framing a theory of value without making any observations at all. Our Medallist, however, would seem to have first approached the problem through his personal contributions to our knowledge of stellar parallaxes.

Following a brilliant career as a graduate student at the Observatory of the University of Princeton, of which he is now Director, Professor Russell came to England in 1902 and entered the Cambridge Observatory as an advanced student. In the year following he was appointed a Research Assistant of the Carnegie Institution, and then embarked upon the photographic determination of stellar parallaxes in collaboration with Mr. Hinks. The undertaking was one of the first of its kind, and the plan of operations demanded much forethought. Mr. Hinks had already carefully prepared a programme of observations and measurements, but being himself occupied with the observations of Eros, the parallax work was left to the care of Russell. The observational work was energetically carried on by Russell until interrupted in

the autumn of 1904 by his serious illness, after which it was carried to completion by Hinks. The measurement and reduction of all the plates, for which Russell assumed responsibility, was commenced at Cambridge and completed at Princeton. The first results were communicated to our Society by him in 1905.* Already we may observe that he was not content to regard the determination of stellar distances as an end in itself. In particular, he was clearly impressed by the importance of the conception of the "absolute magnitude" of a star, which had been proposed by Kapteyn for the proper comparison of stellar luminosities. The apparent magnitude of a star necessarily depends upon the distance as well as upon the actual luminosity, but the absolute magnitude eliminates the effect of distance by supposing all stars placed at a standard distance corresponding to a parallax 0″·1.† From the measured parallaxes Russell found the absolute magnitude of Lalande 21185 to be 10·0, and that of each component of $\gamma$ Virginis to be 3·2, and was thus able to compare their luminosities with that of the Sun (4·8). I mention these results, not because of their intrinsic importance, but as giving some indication of the broad outlook of our Medallist at the very beginning of his astronomical work.

On his return to America, Russell completed the measurement and reduction of the Cambridge plates, and in 1910 published the results for 55 stars.‡ Of particular interest on the present occasion is the discussion of these parallax results in relation to other facts of observation, and especially as regards the bearing of his deductions on the evolution problem. He produced substantial evidence that with increasing redness there was a progressive diminution in absolute magnitude of the fainter stars having large proper motions, in close agreement with the temperature determinations of Scheiner and Wilsing. This conclusion was only applicable to stars of luminosity comparable with, or less than, that of the Sun. Bright stars like Betelgeuse and Antares, which have small proper motions, must be very remote and therefore very bright, and must owe their high luminosity to great superficial area. The densities of such stars might be expected to be very low, and Russell suggested that they were probably in an earlier stage of evolution than the other class of stars. On this hypothesis, he explained, the red stars of types K and M should be of two classes : one of large volume and low density including stars at an early stage of development, and the other of smaller volume and greater density including the stars which were far advanced. In an attempt to account for the great differences in the luminosities of the two classes, Russell very clearly outlined the theory with which his name is now so closely identified.

* *M.N.*, 65, 775, 800.

† If $m$ be the observed magnitude of a star and $\pi$ its parallax, the absolute magnitude is given by $M = m + 5 + 5 \log \pi$.

‡ Carnegie Inst., Washington, Pub. 147, *Astronomical Journal*, October 1910.

He did not then assign distinctive names to the two series of stars, of the existence of which he had become convinced. A similar division of the red stars into two classes, however, had already been made by Hertzsprung,* who had named them "giants" and "dwarfs." These names were subsequently adopted by Russell, and have come into general use.

The great step in advance which our Medallist had made was the recognition of the dependence of the total luminosity of a star upon its density as well as upon its temperature or surface brightness.

Further knowledge of stellar densities thus became to him an urgent necessity, and he set to work on the eclipsing variable stars as the best means of securing it. In 1899 he had discussed the eclipsing variable stars of the Algol type,† and simultaneously with Dr. A. Roberts had shown that a limiting value for the mean density of the components of such a system could be deduced from the period and the duration of its light variation. It appeared clearly that the Algol variables as a class were much less dense than the Sun.

Returning to the subject in 1912, Russell gave a masterly discussion of the whole theory of eclipsing variables.‡ He then showed exactly to what extent the elements of the orbit and the dimensions and brightness of the components of such a system could be deduced from the light-curve, and developed formulæ and tables which make the solution of the problem a comparatively simple matter. The new methods were first applied to W Delphini, W Ursæ Majoris, and W Crucis.§ The first is a typical Algol variable, and, assuming equal masses, the density of the bright star, which is of spectral Class A, was found to be 0·118 that of the Sun. The other two stars, which are of solar or G type, were found to be in striking contrast. While the mean density of the components of W Ursæ Majoris was estimated at 2·2 that of the Sun, the densities of the components of W Crucis were respectively $3{\cdot}1 \times 10^{-5}$ and $1{\cdot}7 \times 10^{-6}$, or approximately 1/30 and 1/550 the density of air at standard temperature and pressure. In one case, therefore, the solar type of spectrum was associated with a higher density than that of the Sun, and in the other with a density a million times lower. Russell naturally concluded that while W Ursæ Majoris must be regarded as having arrived at a late stage of evolution, W Crucis was just as surely at a very early stage of development.

The investigation of other eclipsing variables was energetically pursued by Russell's pupil and collaborator, Dr. Harlow Shapley, and it says much for the convenience of Russell's methods and Dr. Shapley's industry that the results of computations for 87 stars were published before the end of 1913.‖

* *Zeit. f. Wiss. Phot.*, 3, 429 (1905); 5, 86 (1907).
† *Ap. J.*, 10, 315.
‡ *Ap. J.*, 35, 315 (1912); 36, 54 (1912).
§ *Ap. J.*, 36, 133 (1912).
‖ *Ap. J.*, 38, 158 (1913); *Contrib. Princeton Univ. Obs.*, No. 3 (1915).

With this additional information as to the densities of stars, and with the aid of the numerous parallax determinations which had then become available, our Medallist was in a position to make a more determined attack on the great problem which had occupied a foremost place in his mind during several years. I believe I am right in stating that the first presentation of the full data in support of his theory was made by Russell himself at a meeting of our Society in 1913 June.*

In the first instance, his conclusions were based upon the absolute magnitudes of stars calculated directly from measured parallaxes. The results were presented in a beautifully simple and convincing manner in his now well-known diagram, in which absolute magnitudes were plotted as ordinates, and spectral types in the order B, A, F, G, K, M as abscissæ.

Several interesting facts were immediately revealed. Among the stars included in the investigation, all the white ones of Classes B and A far exceeded the Sun (4·8) in brightness, and all the very faint stars were red and of Classes K and M. On the other hand, there were many red stars, such as Arcturus, Aldebaran, and Antares, which were as bright on the average as those of Class A. All the red stars of Classes K5 and M included in the discussion were, in fact, seen to be either very bright or very faint as compared with the Sun.

Russell was fully alive to the danger of making false deductions from data which might be biassed by the principles of selection of stars for parallax determinations, and his conclusions are fully entitled to our confidence. The definite outcome of the discussion, with far more extensive data than had previously been employed, was to prove that there are two great classes of stars: one of very great brightness, averaging about 100 times the Sun's luminosity, and varying but little for the different spectral classes B to M; the other of lesser brightness, and diminishing rapidly in brightness with increasing redness. These are, in fact, the two classes of giant and dwarf stars to which Hertzsprung and Russell had independently directed attention some years before. The separation of the two groups among stars which are of Class K2 or redder was complete, with a clear gap of several magnitudes; there was some intermingling in Classes K, G, and F, while in Classes A and B the two series merged together.

Striking corroboration of the main conclusion was next obtained from a discussion of the absolute magnitudes of about 150 stars belonging to "moving clusters," for which the parallaxes had been determined by indirect methods with a high degree of accuracy.

Another interesting fact emerged from this discussion. It was observed that among the dwarf stars the mean absolute magnitude was a linear function of the spectral type, if B be taken as 1, A as 2, and so on. Russell did not fail to notice the great possi-

* *The Observatory*, 36, 324 (1913); 37, 165 (1914). See also *Popular Astronomy*, 22, 275 (1914).

bilities which may be opened up by this relation. It suggests nothing less than that the absolute magnitude, and thence the distance, of a star may be determined with considerable accuracy by merely observing its spectral type. Russell's diagram also suggested that if in any cluster we find stars which are at the same distance from us, and of comparable brightness, while showing a wide range of spectral types, as from A to K, we may be certain that they are giants of absolute magnitude about 0 or +1, and hence we can estimate the distance of the cluster. It is the extension of this method which, in Dr. Shapley's skilful hands, has enlarged tenfold our conception of the extent of the sidereal universe.

Our Medallist next proceeded to consider the possible interpretations of the great differences in brightness between the giant and dwarf stars of the same spectral class. The factors which really determine the absolute magnitude of a star are the surface brightness and surface area, and the unknown surface area may be expressed in terms of mass and density. There was sufficient reason to believe that stars of the same type have the same brightness per unit surface, and hence a giant star must either have an exceptionally large mass, or an unusually great volume such as would result from low density in a star of average mass. Much depends, therefore, on what can be learnt as to the masses as well as of the densities of stars.

For direct determinations of stellar masses we are entirely dependent upon spectroscopic binaries and visual binary systems for which parallaxes have been determined. There is no evidence, however, that these are different in average mass from other stars, and it was assumed by Russell that they were typical of stars in general. From the data at present available it appears that the range in masses is not great, most of the binary systems being closely similar in mass to the Sun. There is no evidence of stars with masses approaching anything like 100 times that of the Sun, or of any star with a mass as small as one-tenth that of the Sun. The most massive stars, as conclusively shown by Ludendorff in the case of spectroscopic binaries, are those of Class B, and here the average mass is but 7 to 10 times that of the Sun, although some may be 20 times as massive. Thus the total range of stellar masses, so far as they are known, is inconsiderable in comparison with the ten-millionfold range in luminosities.

The conclusion that the masses of stars do not vary greatly from that of the Sun is of great importance, and capable of wide application. It was effectively utilised by Russell in a study of the absolute magnitudes of double stars for which orbits had been computed, but for which parallaxes were unknown. By reversing the usual procedure and assuming the combined masses of the components to be twice the mass of the Sun, it is easy to calculate the "hypothetical parallaxes," and thence the "hypothetical absolute magnitudes," of the component stars. These were not likely to be far from the truth, and indeed Russell con-

vincingly argued that the hypothetical magnitudes were even more useful for his purpose than the true values, because the effects of differences of mass were eliminated, leaving only the differences depending upon surface brightness and density. He also proved that it was possible by a simple statistical process to compute hypothetical parallaxes and absolute magnitudes for all the physical pairs of stars which show even a trace of relative motion. In this way, with the ready assistance of the Harvard observers with regard to spectra, he obtained data for 550 pairs of stars. When the absolute magnitudes and spectra were plotted as in his original diagram, the two series of giants and dwarfs again appeared, and in some respects were even more distinctly displayed than before. The new data showed, for example, that even for equal masses the giant stars of Class K were 100 times as bright as dwarfs of the same spectral type, while in the case of M stars the brightness of the giants was 1000 times that of the dwarfs. It followed at once that the distinction between giant and dwarf stars could not be primarily dependent upon differences of mass.

Differences of surface brightness in stars of similar spectrum and temperature being improbable in view of other researches, there could only be one conclusion. The great luminosities of the giants as compared with the dwarfs of the same spectral classes must be attributed to greater superficial area. This in turn implies a much lower density for the giants. If a giant star of the K class sends out 100 times as much light as a dwarf of equal mass and surface brightness, its diameter must be ten times that of the dwarf, and its density consequently only one-thousandth as great. Similarly, a giant of Class M a thousand times as bright as a dwarf of the same spectral type would have a density less than one-thirty-thousandth that of the dwarf star.

The possibility of the existence of stars having such extremely low densities might well have been questioned, but Russell was able to point to his results for eclipsing variables, where the actual existence of several stars of Classes G and K with correspondingly low densities was very definitely indicated.

With almost superfluous caution, our Medallist sought further justification for the supposition that the spectral order BAFGKM, which was at the root of his investigations, was really a scale of diminishing surface brightness. Hitherto he had depended mainly upon the evidence that it was a scale of decreasing temperature which was afforded by laboratory experiments on the interpretation of the spectral lines occurring at different stages of the stellar sequence, and by spectro-photometric observations of the distribution of intensity in the continuous backgrounds of the stellar spectra. These spectro-photometric observations had, in fact, shown that there was a regular decline from the B stars, with a temperature of upwards of 14,000°, to the M stars with a temperature of the order of 3000°, and, in accordance with the laws of radiation, a corresponding decrease of emissive power per unit

surface was to be expected. Russell, however, showed that independent evidence of the rapid decrease of surface brightness with increasing redness might be obtained from the stars themselves, assuming only that eclipsing binaries and telescopic double stars of the various spectral classes might be taken as typical of such classes as a whole. One illustration will suffice. If each of the fifty eclipsing binaries of Class A had the same mass and surface brightness as the Sun, but its own density, the average absolute magnitude would be 3·06. The results previously obtained for 115 visual double stars of Class Ao, however, showed that if these stars were equal to the Sun in mass only, and had their own surface brightnesses and densities, the mean absolute magnitude would be 1·07. On the average, therefore, the stars of Class A, for equal surfaces, must be two magnitudes brighter than the Sun. In a similar manner it was proved that for masses equal to that of the Sun, in passing from Class B to Class G, there is a reduction of surface brightness equivalent to about one magnitude from each class to the next. These conclusions are not only in agreement with the supposition that the differences in spectral type are directly associated with differences in temperature, but furnish a proof which is quite independent of any chemical or physical interpretation which may be put upon the actual spectra.

With characteristic thoroughness, our Medallist made further effective use of the observational data which he had so diligently collected as a means of estimating the most probable densities of the redder giant stars, and the average masses of stars of the various spectral classes. The mean absolute magnitude of the giant stars of Class G and redder which occur among the double stars, if of the same mass as the Sun, was found to be 0·44, corresponding to a luminosity 50 times that of the Sun. Thus a giant of solar type (Class G) with a mass and surface brightness like those of the Sun, must be swollen to 7 times the Sun's diameter, so that its density would be about 1/350 that of the Sun. The estimation of the densities of the redder classes requires a knowledge of the rate of diminution of the surface brightness with spectral type, but, adopting provisionally the ratio derived from dwarf stars, Russell thus derived a density of 1/2800 that of the Sun for giants of Class K, and 1/25000 that of the Sun for giants of Class M. These values are in satisfactory agreement with those previously deduced from eclipsing variables so far as the scanty data permit a comparison. There is, unfortunately, no M star among the known eclipsing variables, and therefore no observational confirmation of the extremely low density assigned to stars of this class; in the case of W Crucis, however, the density was found to be still lower.

For the determination of the average masses of the stars of the different classes, Russell made a statistical comparison of the actual absolute magnitudes of the stars of different groups and those which double stars would exhibit if equal in mass to the

Sun. It will suffice to state that the outcome of the investigation was to show that there was a moderate decrease of average mass of the dwarf stars with increasing redness, to which I shall have to refer again.

All these new facts with regard to stellar masses, densities, and luminosities were woven by our Medallist into a consistent whole in a more extended presentation of the theory which he had foreshadowed three years before. The essential feature of the theory is that the order of stellar evolution is the order of increasing density. The earliest phase in the history of a star as a star must therefore be represented by the giant red stars of Class M, which are the least dense and most diffuse. In general, the lower the density the more primitive the star.

Through the increase of temperature accompanying contraction, in accordance with Lane's law, the star will pass successively through the giant stages represented by Classes K, G, F, A to Class B, when it will reach the maximum temperature. During these changes the superficial area will be diminishing, but the surface brightness will be increasing, and the total luminosity of the star will vary but little. The colour of the star, however, will pass from red to white, and there will be modifications in the spectral lines in correspondence with change of temperature and physical conditions of the absorbing atmosphere. On arriving at the B stage, the density will have increased to such an extent that the laws of perfect gases cease to hold, and the temperature will fall. With increasing density, decreasing volume, and diminishing surface brightness, the luminosity of the star will rapidly fall, and it will pass successively through the dwarf phases represented by the spectral Classes A, F, G, K, M. The two series of giant and dwarf stars are thus united into a single sequence of gradually increasing density, with the hottest stars in the middle. All the spectral classes except the hottest stars of Class B will thus appear twice, but in inverse order in the two halves of the sequence; thus—

| Typical Giants. | | Highest Temperature. | | | | | Typical Dwarfs. |
|---|---|---|---|---|---|---|---|
| Bellatrix | | | B | | | | |
| α Cygni | Giants of | | A | A | | Dwarfs of | Sirius |
| Canopus | constant | | F | F | | decreasing | Procyon |
| Capella | luminosity | G | | | G | luminosity | Sun |
| Arcturus | | K | | | K | | 70 Ophiuchi |
| Betelgeuse | | M | | | M | | Krüger 60 |
| | | Lowest density | | | Greatest density | | |

There can be no question as to the general agreement between the actual characteristics of the giant and dwarf stars of the various spectral classes which have been described and those which might be expected on Russell's theory. In particular, the densities

actually found from the observational data are in very close accordance with those required by the theory. Giants of Classes G, K, and M have densities so low that they must get hotter if they contract. The Sun, on the other hand, has so great a density that it must have passed the critical stage beyond which the laws of perfect gases are no longer applicable, and must therefore be a dwarf star. Of crucial importance for the theory is the fact that the densities of stars of Classes A and B, about one-ninth that of the Sun, are of the order of magnitude at which Lord Kelvin predicted that the highest temperature would be reached.

The same stellar mass, it should be observed, will appear first as a giant red star of enormous volume and low density, and after the lapse of many millions of years will become a dwarf of small volume and high density. Russell found, however, from an extension of Lane's law, that the actual history of a star in the interval will be dependent upon its mass. A star of large enough mass would pass through all stages from M to B and B to M again, but a smaller mass would only reach as far as Class A, a still smaller mass to Class F, and so on. The theory indicates that throughout all the changes a massive star would reach a stated temperature at a lower density in the giant stages, and on returning to that temperature when on the downgrade would have a higher density than one of smaller mass. Very small masses would never reach a very high temperature, and might not even become luminous at all. It follows, therefore, that there may be stars which are giants in a double sense. A star of moderate mass may be a giant in the sense that it is very diffuse and at an early stage of evolution, but other stars may be giants in mass as well as in volume.

The deduction as to the effect of mass on the highest attainable temperature gives greater elasticity to Russell's theory, and has several applications of high importance. By making large mass an essential condition for the development of stars of Class B, for example, it at once accounts for the greater observed masses of stars of this class, which, it should be borne in mind, are relatively few in number. It also enables us to understand, as Russell explained, why the average masses of the stars should diminish with increasing redness, since it is here, on both sides of the temperature curve, that smaller masses would occur in greater proportion and so lower the average. Observational results which may at first have seemed to be mutually inconsistent, were thus justifiably regarded by Russell as furnishing important evidence in favour of his theory.

The effect of differences of mass also enabled Russell to give the first acceptable explanation of the progressive increase of the "peculiar" velocities of the stars in passing from Class B to Class M which had been observed by Campbell and Boss. On the older theory, it appeared that the velocity of a star increased with its age, and no reason for such an increase could be assigned. On the simple and reasonable assumption that stars having the largest

masses have the smallest velocities, Russell was able to account for all the main features of the velocity relationships. The B stars, according to the theory, must all be massive, and the average velocity is therefore low. The A class will include some stars of large mass which are on their way to the B stage, and some of rather smaller mass and higher velocity which are not destined to reach a higher temperature, and the average velocity will therefore be somewhat greater than in Class B. In Class F, again, a greater proportion of less massive stars with higher velocities will be included, and the average speed will be increased. This increase will be continued throughout the series of classes, but only so long as each class includes stars which have reached the maximum temperature corresponding with their masses.

This admixture of stars of various masses will naturally tend to mask the distinction between the giants and dwarfs, as is actually observed in Classes G, F, and A. From the clear separation of the giants and dwarfs in Classes K and M, however, it would appear that most of the stars which get into our lists are of sufficient mass to develope beyond these stages, so that the mean masses and velocities in these classes should be nearly the same as in Class G. That is, the rate of increase of average velocity between Classes G and M should be less than between Classes B and G; and this is exactly what is observed.

Our Medallist did not attempt to explain the assumed correlation between mass and velocity, but he drew attention to substantial evidence for its existence. Giants which are of exceptional brightness in consequence of unusually large masses, if the assumed relation be true, should be moving with lower velocities than the average for stars of the same spectral classes. The Cepheid variables would appear to be stars with these characteristics; they are undoubtedly of very high luminosity, and their mean peculiar velocity, deduced independently by Russell and Hertzsprung, is little more than half the average for the stars of Class G to which they belong. A similar result was found for the stars with unusually sharp lines distinguished as having the "*c*" characteristic in the spectral classification of Miss Maury, all of which seem to be of quite exceptional luminosity and to have less than the average velocity for their spectral classes. Both the Cepheid variables and the "*c*" stars are thus potential B stars, which they resemble in their strong condensation towards the Milky Way.

Further support for his views was found by Russell in the relative proportions of the number of stars of the different spectral classes, interpreted as indicating a more rapid rise to maximum than fall to minimum temperature, and in the relative percentages of spectroscopic binaries of different spectral types.

Having found so much in favour of the theory which he had so diligently developed, however, our Medallist did not neglect to mention some of the things which were for the time being not included within its scope. Thus, while all the classes of stars from B to M were satisfactorily included in the evolutionary scheme, it

was considered premature to attempt to place the stars of Class N, of which little was known except that they were giants of great luminosity and redness and might therefore possibly precede the giants of the M type. Observational data for the O, or Wolf-Rayet, stars were similarly found to be inadequate for a complete discussion of their relationships, but Russell thought it not improbable that some of them should be placed above the B stars at the apex of the temperature curve, where they had also been placed by Lockyer.

A more notable omission from the evolutionary scheme is that of the irregular gaseous nebulæ, which were previously regarded as the most primitive of all the celestial bodies. For Russell, the primordial matter out of which stars are developed is apparently non-luminous, and he has as yet expressed no opinion as to the nature of the luminous nebulæ, except that they are as likely to be the offspring as the parents of stars.

Russell's theory of stellar evolution, it will have been observed, bears considerable resemblance to that of Lockyer. The criteria for classification, however, are fundamentally different in the two cases. The sequence of spectra arrived at by Lockyer was based upon the spectra alone, while that deduced by Russell depends upon considerations as to the absolute magnitudes and densities of the various classes of stars as well as upon their spectra. The B stars, and the stars having the "*c*" characteristic, occupy similar places in the two systems; but otherwise Lockyer's criteria did not enable him to distinguish the giants from the dwarfs. Thus Lockyer placed all the M stars in a single group as representing the first stage of condensation from nebulæ, but Russell has shown that there are many stars of this class of low luminosity and great density which cannot be regarded as at an early stage of evolution, though none of these were bright enough to appear among the stars classified by Lockyer. Again, many stars such as Capella and Arcturus, and all the N stars, were placed by Lockyer near the end of the sequence, whereas in Russell's classification they occur near the beginning.

Our Medallist did not omit to consider a question which has doubtless occurred to all of us; namely, what precedes the giant stars of Class M? In view of the great luminosity of stars of this class, it might reasonably have been expected that some earlier phase of stellar history would be represented by visible bodies. In the first instance, it was argued that in the most primitive conditions the greater part of the radiant energy would be in the infra-red and therefore invisible, and that a star might not begin to shine effectively until it reached an effective surface temperature of about 3000°. This answer to our question, however, could scarcely be regarded as final, and Russell conscientiously returned to the subject in a consideration of the possible sources of stellar energy.*

It is now generally acknowledged that the energy available

* *Pub. Ast. Soc. Pac.*, **31**, 205 (1919).

through the gravitational contraction of a gaseous mass is quite inadequate to account for the long duration of the radiation emitted by the Sun and stars. Besides the evidence from geology, Eddington has shown that if the heat due to contraction were the only source of supply, a typical stellar mass would run through the giant stages M to G in 18,000 years at the most; and there is good reason to believe, from the study of Cepheid variables, that the actual process of development through these stages is so prolonged that a period of this duration is insignificant. To meet this difficulty, Russell has suggested that there is an "unknown source" of energy within the stars, and has shown that there is little difficulty in specifying the conditions under which it must be released in order to conform with a nearly steady state of slow radiation through the various evolutionary stages. He did not speculate as to the nature of the hypothetical source, but pointed out that the conditions would be met by such sources as atomic disintegration or mutual neutralisation of positive and negative electric charges. Eddington, however, is bold enough to suggest that the unknown source may very well be the energy set free by the synthesis of more complex atoms from atoms of hydrogen, as suggested by the recent work of Aston on the atomic masses of the elements.

Granted such a source, the abrupt appearance of highly luminous red stars of Class M at the earliest stage of stellar development becomes more comprehensible; it is only necessary to assume that the interior of a giant star does not reach the temperature at which the unknown source becomes important until its effective surface temperature has reached the value characteristic of Class M. Stars in a more primitive state, depending solely upon gravitational contraction for their supplies of radiant energy, would run their courses so rapidly that there would be very few of them in a given region of space at any one time, and they might thus escape observation.

An observation which may have a bearing upon this question has since been made at Mount Wilson by Merrill, who has found that some of the most characteristic lines of the gaseous nebulæ are present in the spectrum of R Aquarii, which is otherwise of M type. So far this is an isolated example, but in view of Russell's argument as to the probable rarity of luminous stars in a state antecedent to the giants, it is perhaps possible that R Aquarii may actually represent a transition from nebulæ to giants of Class M. Russell considered the development of the M stars from non-luminous diffuse matter, but Merrill's observation strongly suggests to me that the irregular gaseous nebulæ may still find a place at the very beginning of the evolutionary sequence.

Better testimony to the importance and suggestiveness of the contribution to the theory of stellar evolution which has been made by our Medallist could scarcely be desired than that afforded by the striking confirmations of some of its leading features which have been announced since the theory was first launched.

Foremost place should perhaps be given to the brilliant proof of the existence of giant and dwarf stars obtained by Adams in his spectroscopic determinations of absolute magnitudes and parallaxes.* At each stage of the spectral series from Class M to Class F these observations clearly proved, in accordance with Russell's results, that there are two distinct series of stars, one of which remains at an average absolute magnitude of about +1 throughout, while the other ranges from an average of +4 in the F class to +11 in Class M. For the M stars, the difference in average luminosity of the two classes is nearly 10 magnitudes, corresponding to a ratio of 10,000 to 1 in the actual light emitted by the giants and dwarfs. Further, there was a clear separation of about 6 magnitudes between the two M groups in which no stars were found, although the selection of stars observed would have included such stars if they had any existence. Differences in spectrum between giant and dwarf stars of the same spectral classes could not be expected to be very conspicuous in view of the mode of spectral classification, but actually they are so distinct that a mere glance at the spectrum is now often sufficient to distinguish a giant from a dwarf. Moreover, the varying relative intensities of the lines on which the distinction is based are such as admit of ready explanation by the different physical conditions in the absorbing atmospheres of the two classes of stars. Any doubt which may have been felt as to the existence of giant and dwarf stars was thus finally dispelled.

On the theoretical side, the behaviour of a condensing mass of gas of low density has been investigated by Eddington,† and by Jeans,‡ with results emphatically favourable to Russell's theory. Professor Eddington has shown that a rarefied giant star will adjust itself to a state of equilibrium in which a considerable fraction of gravity is counterbalanced by the pressure of the escaping radiation from the interior, and has obtained relations between the mass, density, and effective temperature which have enabled him to estimate the average densities of the giant stars of different spectral types, the maximum effective temperature attainable by a given mass, and the probable range of stellar masses. Thus, considering a mass equal to $1\frac{1}{2}$ times that of the Sun, it was found that for effective temperatures ranging from 3000° to 13,000° the densities range from 0·00002 to 0·128 (water = 1), in close agreement with Russell's estimates of densities for the corresponding classes of stars from the observational data.

One of the most striking results obtained by Eddington is that the total radiation of a gaseous star, so long as it remains in the giant stage, is independent of the stage of evolution which it has reached, and depends only upon its mass. Theory and observation are again in close accordance, for one of Russell's most fundamental conclusions is that giant stars of all spectral

* *Proc. Nat. Acad. Sci. Wash.*, **2**, 143–157 (1916); *Ap. J.*, **46**, 313 (1917).
† *M.N.*, **77**, 16 (1916); *Brit. Ass. Rep.* (1920).
‡ *Problems of Cosmogony*, p. 201.

types have nearly the same luminosity. The observed differences of one or two magnitudes are readily accounted for by variations in mass, and by differences in the ratio of the luminous to the total radiation at different temperatures. The conclusion that the luminosity of a giant star is nearly proportional to its mass (or, if there is strong internal ionisation, to the square of the mass), taken in conjunction with the facts as to the luminosities collected by Russell, further led Eddington to the important result that the range of stellar masses is very small, and of the same order as indicated by the masses of binary stars, so that limits of mass in the ratio 3 : 1 would include the great majority of the giant stars. Russell's assumption that the masses of stars in general are similar to those of binary stars was thus theoretically justified.

Further general agreement between theory and observation was found by Eddington in his determination of the turning point at which the effective temperature of a star ceases to increase with the density. For a star $2\frac{1}{2}$ times the mass of the Sun, the calculated maximum effective temperature was 14,000°, and for one only half the Sun's mass 6000°, not widely different from the temperatures assigned to corresponding stars by Wilsing and Scheiner from their spectro-photometric observations. Expressing the result in another way, Eddington found that a star must have not less than one-seventh of the Sun's mass in order to appear even at the lowest spectral type M, and that it is not likely to reach the B stage unless it is at least $2\frac{1}{2}$ times as massive as the Sun. No star with a mass less than one-seventh that of the Sun is in fact known, and there is abundant reason to believe that the B stars are the most massive.

In the dwarf stages, according to Eddington's investigations, the importance of radiation pressure in comparison with gravitation decreases rapidly from the B stage, so that in the Sun, which is a typical dwarf, it is practically negligible. The densities of the dwarf stars must lie between 0·2 and 3 or 4, and the fall in luminosity must be mainly due to decrease of temperature, since the superficial area will not greatly change.

It was doubtless a source of intense satisfaction to our Medallist to find that the theory of stellar evolution which he had deduced from observational data so well withstood the searching tests to which it had been submitted by the theoretical researches of Eddington.

A considerable body of evidence which supports Russell's views has also been found by Jackson and Furner * in their recent investigation of the hypothetical parallaxes and absolute magnitudes of 556 visual double stars. The discussion of these in relation to spectral types very definitely confirmed the division of the redder stars into giants and dwarfs which was indicated by Russell's original investigation.

A more sensational piece of evidence was still in store. The possibility of making direct measurements of the angular diameters

* *M.N.*, 81, 2 (1920).

of some of the stars by an application of the interferometer was long ago suggested by Michelson and others, and the recent attempts to utilise this method at Mount Wilson were crowned with success on December 13 of last year, when Mr. Pease and Dr. Anderson obtained satisfactory measurements of Betelgeuse. Estimates of the apparent diameters of several stars had already been made by Eddington,* Russell,† and others, depending upon determinations of surface brightness corresponding to the various spectral types or colour-indices. For Betelgeuse, Eddington predicted an apparent diameter of 0″·051, and Russell 0″·031. The Mount Wilson value from actual measurement was 0″·045, in close agreement with the mean of the two predicted values, 0″·041. From the measured parallax it follows that Betelgeuse has a diameter about 300 times as great as that of the Sun, and unless an altogether improbable mass is assigned, its density must be extremely low. Betelgeuse, at least, is an undoubted giant star.

The question of the existence of giant stars is no longer a matter for discussion. Any acceptable theory of stellar evolution must take account of them, and Russell's theory represents the only attempt which has yet been made to give a rational explanation of the part which they play in the general scheme of stellar development. The theory itself has the great merit of simplicity, and it violates no known physical laws. Russell has led us step by step from the simple conception of giant stars to a consistent explanation of a multitude of phenomena, so that the scope of the theory has become almost as wide as the universe itself. The theory has already had a profound influence on astronomical thought, and seems destined to be of great value in directing the future course of astronomical research.

It is to our Medallist's gift of imagination, coupled with untiring industry and an extraordinary mastery of detail, that we owe this stimulating theory of cosmical processes. For this, and other notable contributions to our science, we are proud to include his name on our roll of honour.

Professor Russell: In presenting to you this Gold Medal on behalf of the Royal Astronomical Society, I ask you to accept it as an expression of our esteem, and of the interest and appreciation with which we have long followed your work on the great problem of stellar evolution. We trust that your life may long be spared, and that you may have health, strength, and opportunity to continue your devoted labours for the advancement of our science. Allow me also to say that it is to me a source of sincere gratification that it has fallen to my lot to be the means of conveying to you in person this token of the highest honour which it is in the power of the Society to bestow.

* *B.A. Report*, 1920.
† *Pub. Ast. Soc. Pac.*, 1920 December.

*Election of Officers and Council.*

The Meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected:—

*President.*

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